Aircraft Safety Belts:
Their Injury Effect On The Human Body

BY

Hugh De Haven
Boris Tourin
Salvatore Macri

CRASH INJURY RESEARCH

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Cornell University Medical College
1300 York Avenue, New York 21, N.Y.

EDITORIAL

Support Crash Injury Research

Washington budget-slashing and talk of getting more out of every federal dollar spent raises the possibility that some vital activities may be chopped off or crippled simply because their returns have not been sufficiently publicized or appreciated by top policy-making officials.

One little group which has pioneered successfully in the commendable objective of saving human life is the Crash Injury Research project of Cornell Medical College. Everyone should know more about its work.

There now is almost universal acceptance of the value of accident prevention. But the Crash Injury Research project has gone a significant step further—it works to reduce the toll of injuries and deaths in those accidents which do occur. Its accomplishments are impressive, and it has proved that greater achievements are attainable in the future if it can be allowed to continue its mission.

Crash Injury Research was established in 1942, under its present director, Hugh DeHaven, and operated until the end of the war with funds provided by the Office of Scientific Research & Development. During this period, members of the project worked directly with the Navy and Air Force to establish parallel crash-injury studies by military groups. More recently, annual support has come from the Office of Naval Research, the Air Force, Army, Navy and Civil Aeronautics Administration.

This project set up at Cornell Medical College the first acceleration-deceleration facilities for testing shoulder harness. It built the first dynamic testing apparatus for 40G seats. It developed an inertia lock for military shoulder harness. It arranged a forum for discussion of civil and military safety problems at five crash injury research conferences held at the National Academy of Sciences under the auspices of the National Research Council.

But even beyond these contributions, the project—working with other divisions of Cornell University through the Cornell Committee for Transportation Safety Research—has been directly responsible for a widespread stimulation of design and engineering thought which has led to a growing realization by engineers that safety in aviation must also include the protection from injury in crackups.

Using crash-injury findings from previous accidents, engineers have achieved a valuable increase of safety by devising structures and installations which reduce exposure to injury in survivable accidents.

CIR has worked extensively with civilian aircraft designers. However, its findings—that human structures and aircraft structures can tolerate the force of severe crashes—have directly complemented the excellent safety studies conducted by the Directorate of Flight Safety Research, the Aeromedical Laboratory, and the Office of the Surgeon General of the Air Force, as well as studies by the Flight Safety Division of the Office of the Chief of Naval Operations and the Navy's Bureau of Medicine and Surgery.

The design of crashworthiness into personal, agricultural and executive aircraft has automatically contributed to safety in "off the shelf" liaison and light transport aircraft now used by the Army, Navy and Air Force.

It has contributed to increased safety in large transport planes, as well. One notable example is the major redesign in forward-facing passenger seats, attachments, and safety belt installations which have been the direct result of observations on the dangers set up by steel seat backs in small planes.

The effectiveness of new design in forward-facing seats now is being studied by the project for comparison with accident-injury data on the safety of rearward-facing seats based on data from British civil and military experience as well as from other sources.

CIR's stimulation of research on problems of impact, energy absorption, crash force recorders, kinematic effects of the body on safety belts and measurement of force in controlled crashes, has contributed to an interchange of concepts, studies and findings which have served effectively in increasing the safety of military and civilian flight.

Although the engineering art of providing protection in accidents is still young, there is signal evidence of the effectiveness of CIR's project in recent extension of crash-injury studies developed in aviation to the automotive field where many of the measures now used to give more safety in aircraft accidents can be applied in passenger automobiles.

Despite CIR's humane, unique mission to save life for civilian as well as military personnel, and in ground vehicles as well as in aircraft, this project—like all government-supported research programs working under the "one-year edict"—lacks any assurance of funds for long-term continuation.

A short-term policy for long-term, effective safety research is no more in accord with good business practices of government than short-term, spasmodic spurts and slumps in our vital military aircraft production program if our national welfare is to be promoted at maximum efficiency and effort.

Crash Injury Research Project merits the continued support of its federal sponsors whose foresight has already contributed to CIR's effective return in the saving of human life.

—Robert H. Wood

AIRCRAFT SAFETY BELTS:
THEIR INJURY EFFECT ON THE HUMAN BODY

An analysis performed under a special grant
by the Civil Aeronautics Administration

by

Hugh De Haven
Boris Tourin
Salvatore Macri

July, 1953

Crash Injury Research
Department of Public Health and Preventive Medicine

Cornell University Medical College
1300 York Avenue, New York 21, N.Y.

FOREWORD

Crash Injury Research, a Project working under Office of Naval Research Contract N6onr 264-12, is jointly supported by funds provided by the United States Departments of the Army, Navy and Air Force and the Civil Aeronautics Administration. The recommendations appearing in this paper do not necessarily constitute official opinions of the sponsoring groups.

The Project is a part of the Department of Public Health and Preventive Medicine headed by Dr. W. G. Smillie, and is under the direction of Hugh De Haven at Cornell University Medical College in New York City.

Data were analyzed and the report was prepared by Boris Tourin, Executive Analyst, in collaboration with Hugh De Haven, Director. Salvatore Macri, Accident Analyst, assisted in the compilation of all basic data.

Crash Injury Research is particularly indebted to Dr. Irwin D.J. Bross, Associate Professor (Vital Statistics) in Cornell's Department of Public Health and Preventive Medicine. The Project also gratefully acknowledges the technical guidance of Dr. John D. Coakley of Dunlap and Associates, Inc. and Dr. Barry G. King, Research Executive, Medical Division, of the Civil Aeronautics Administration.

ABSTRACT

A study of 1039 survivors of lightplane crashes - ranging from moderate to extremely severe in nature - has been made in order to factually evaluate the injury effects of 2 inch lap-type safety belts with a loop-holding capacity from 1000 to 2000 pounds.

The results of 64 statistical tests are presented and the following conclusions are drawn:

1. There is no correlation between severe snubbing action of safety belts (as evidenced by bruises and contusions of hips and abdomen) and the occurrence of intra-abdominal injuries or injuries of the lumbar spine;

2. The occurrence of injuries which are dangerous-to-life is related to objects and structures or the transmittal of force through seats, rather than to safety belts;

3. Injuries of the neck, torso and spine are not related to the use or non-use of safety belts, but injuries of the head - including head injuries which are dangerous-to-life - and dangerous injuries of the head and body as a whole, are increased when the belt is not used;

4. Injuries of the upper and the lower torso are associated with and increased by failure of safety belt installations;

5. Failure of safety belt installations increases the incidence of all degrees of injury of the head, as well as the occurrence of dangerous-to-life injuries of the head and body as a whole;

6. Injuries of the head, both non-dangerous and dangerous, are associated with and increased by forces acting principally in parallel relation to the longitudinal axis of the plane;

7. Forces which act principally in a vertical direction through the seats account for increased rates of (a) dangerous injuries to the head and body as a whole, (b) all types of lumbar and dorsal spine injuries, and (c) intra-abdominal injuries.

The statistical findings demonstrate that:

1. The safety belt is not "dangerous";

2. The safety belt provides protection for the body in crashes; and

3. Injuries which may have seemed related to safety belts directly actually are determined by other factors such as safety belt installation failures and vertically acting forces in accidents.

The findings indicate that a significant decrease in exposure to crash injuries in small planes can be achieved by:

1. Providing safety belt installations (webbing, hardware, carry-through and anchorage points) which will hold occupants in place under conditions of crash force which leave cockpit and cabin structures reasonably intact;

2. Wearing safety belts;

3. Using shoulder harness to prevent forcible contact of the head and upper torso with structures or objects having dangerous injury potentials:

4. Designing the landing gear, fuselage, floor and seat structures to progressively absorb vertically acting crash force.

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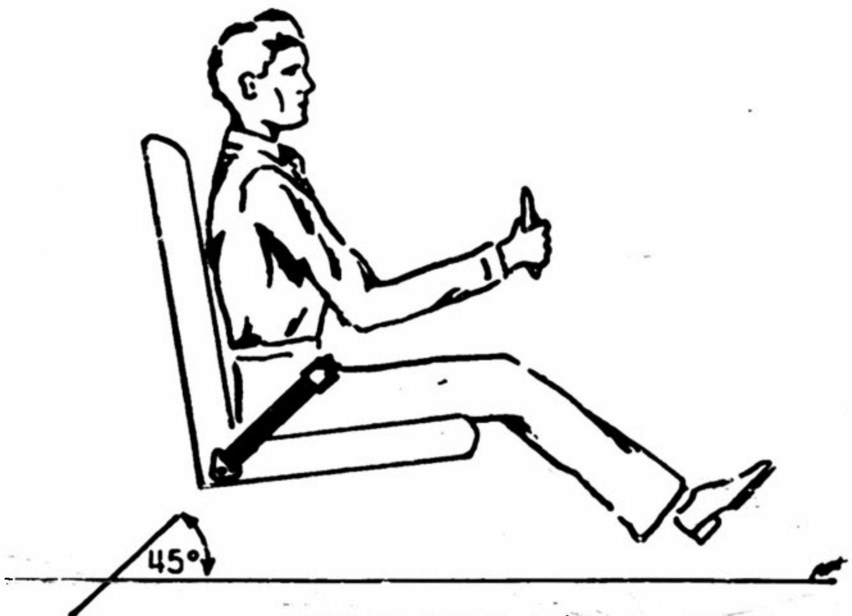

WEBBING PASSES OVER JUNCTURE OF
THIGHS AND PELVIS AT APPROXIMATELY
45° TO LONGITUDINAL AXIS OF AIRPLANE.

FIGURE 1: TYPICAL SAFETY BELT INSTALLATION IN CIVILIAN AIRPLANES USED FOR CCIR STUDY.

INTRODUCTION

Ever since safety belts were first installed in aircraft, their use has been challenged because of the belief that they caused serious bodily injuries. It was held, for example, that the snubbing action of lap-type safety belts (see Figure 1) with a loop-holding capacity of 2000 lbs. (see Figure 6, page 14) was a direct cause of ruptures of abdominal viscera. Rumors, usually based on conclusions drawn from violent, disintegration-type crashes also perpetuated the belief that safety belts cut the body in two in severe accidents. Also, it was maintained that the snubbing action of safety belts resulted in "acute flexion" of the torso with consequent damage of internal organs and the spine.

On the other hand there are those who were inclined to over-rate the protective values of the safety belt - and consequently under-rate the value of shoulder harness and the need of crashworthiness and improved design of cockpit and cabin installations.

These opposing views demonstrated the need of *facts* for evaluating the injury effects of aircraft safety belts. This report studies injuries sustained by 1039 survivors[1] of 670 lightplane crashes and relates these injuries to their causes. Statistical analyses have been employed to determine whether safety belts used in U. S. civil aircraft protect or endanger the body in crashes.

METHODS and PROCEDURES

The first step in the study was to select data which would be pertinent to the problem. *APPENDIX I* describes the nature of CIR data and gives the rationale for the extraction of cases which were studied.

One of the primary bases for analysis was a comparison of injuries which were caused (1) directly by the belt and (2) indirectly by the belt and/or not by the belt at all. Further analyses examine the influence of other factors possibly related to injuries by comparing rates of injury (1) when the belt was used and was not used, (2) when safety belt installations remained

[1] ALTHOUGH THIS REPORT DEALS WITH 'SURVIVORS'-PERSONS WHO LIVED FOR 24 HOURS SUBSEQUENT TO THE ACCIDENT-IT SHOULD NOT BE PRESUMED THAT ALL THE INJURIES WERE SURVIVED. OF THE 1039 SURVIVORS, 306 WERE INJURED TO A 'SERIOUS' OR 'CRITICAL' DEGREE. THIRTY-SEVEN OF THESE SURVIVORS WERE REPORTED TO HAVE DIED OF THEIR INJURIES 24 OR MORE HOURS AFTER THE ACCIDENT. IN THESE CASES, CAUSES OF DEATH WERE APPARENT WITHOUT NEED OF AUTOPSY, AND MEDICAL DATA WAS SUFFICIENTLY DETAILED TO CONFIRM AN EXTREMELY LOW INCIDENCE OF INTRA-ABDOMINAL AND INTRA-THORACIC INJURIES.

intact or failed, and (3) when the principal direction of crash force acted in vertical or parallel relation to the longitudinal axis of the plane. The comparisons were based on percentages of survivors sustaining varying classes and combinations of injuries of all degrees, including dangerous-to-life injuries[1]. *APPENDIX 2* lists the classes and combinations of injuries studied and the numbers of survivors sustaining these injuries.

A tally of the number of injuries for each class and combination of injury permitted early comparisons of injury rates. Conclusions based on percentages were then tested for validity by statistical analyses applied to each set of conditions which might be a factor in causing injury. For example, the rates of survivor-injury when belts were used and when belts were not used were statistically compared by Chi-square methods to determine whether any difference in rates of injury was significantly related to the fact that the belts were used or not used - or whether any difference was attributable to chance. The methods employed and various statistical considerations form a portion of the ANALYSIS section of this report. Numerical data, percentages and statistical computations are shown in *APPENDICES 2 and 3.*

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1 CIR'S SCALE OF INJURY-SERIOUSNESS, DEFINING 6 PROGRESSIVE DEGREES OF NON-FATAL INJURY (OF WHICH THE LAST 2 DEGREES ARE CLASSED AS 'DANGEROUS-TO-LIFE') IS SHOWN IN APPENDIX 4.

SECTION I

BASIC DATA

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PART I: Body Areas Injured

Examination of the pattern of injury[1] sustained by the 1039 survivors studied for this report reveals that the following percentages of survivors sustained injury in the body areas indicated below:

BODY AREAS	PERCENTAGE OF SURVIVORS INJURED
HEAD	79.9
NECK (including cervical spine)	6.1
UPPER TORSO (including dorsal spine)	19.8
LOWER TORSO (including lumbar spine)	23.9
SPINE (as a unit comprising cervical, dorsal and lumbar spines)	15.8
EXTREMITIES	59.1

It will be observed that the head is injured more than 3 times as often as the lower torso, which is adjacent to the safety belt and which includes, in addition to the abdomen and its contents, the lumbar spine, the pelvis-sacrum, hips, buttocks, perineum and genitalia. Nevertheless, merely because all these portions of the lower torso are injured less frequently than the head, does not mean that the safety belt is not dangerous. The number of survivors with lower torso injuries (248 out of 1039) is still a matter of concern in assessing the presumed dangerousness of safety belts. These 248 cases provide a basis for critical statistical analyses to determine whether many, all, or only a few of the lower torso injuries are attributable directly to the belt, and also how many of these belt-injuries are dangerous to life. However, statistical study is necessary to determine not only relationships between *primary causative factors and lower torso injuries*, but also between these factors and injuries in *other gross areas of the body*.

1 THE PATTERN OF INJURY SUSTAINED BY THE 1039 SURVIVORS STUDIED FOR THIS REPORT CLOSELY RESEMBLES INJURY-PATTERNS DISCUSSED IN EARLY CIR REPORTS:

A. NRC COMMITTEE ON AVIATION MEDICINE REPORT #230, NOVEMBER, 1943: 'INJURIES IN THIRTY LIGHT-AIRCRAFT ACCIDENTS', BY HUGH DE HAVEN, CORNELL UNIVERSITY MEDICAL COLLEGE.

B. CRASH INJURY RESEARCH REPORT, JULY, 1952: 'THE SITE, FREQUENCY AND DANGEROUSNESS OF INJURY SUSTAINED BY 800 SURVIVORS OF LIGHTPLANE ACCIDENTS'.

PART II: Number of Survivors Using Belts: Types of Belt Installation Failures

Data extracted from case records of the 1039 survivors were tallied according to use and effectiveness of safety belts. By chance, exactly 1000 of the survivors used their safety belts; 39 did not.

Figure 2 shows the numbers of survivors whose belt installations remained intact - or failed - when seats remained in place. The relatively high incidence of belt installation failure (nearly 25% of installations failed) immediately suggests that belt installation failure may be a factor in dictating injury patterns. This observation therefore was tested and analyzed in subsequent sections of the study.

Breakdown of failures of safety belt installations into types of failure revealed that the various categories of failure were too small for analysis in relationship to injuries. The breakdown, however, may be of some interest to engineers and safety groups and is therefore presented in Figure 3.

Effectiveness of Safety-Belt
Installations among 1000
Safety-Belt Users

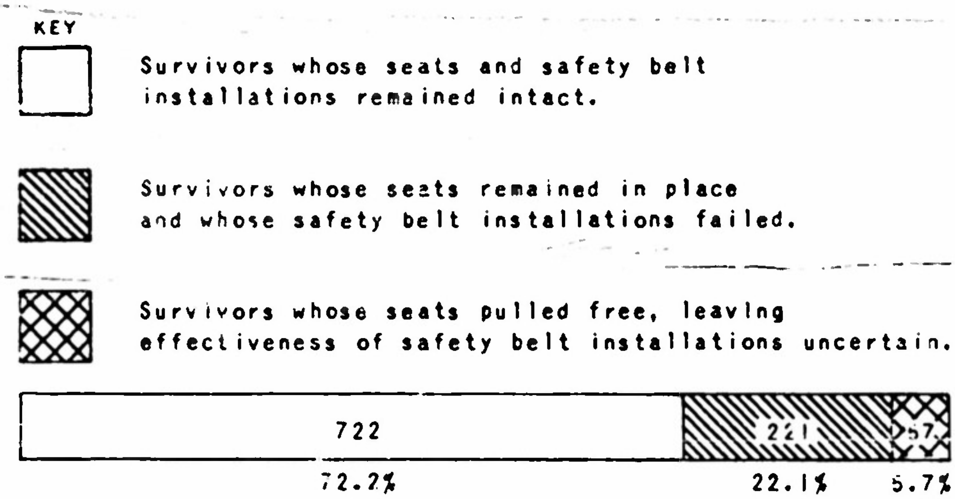

FIGURE 2

Types of Safety Belt Installation Failures
in
221 Cases where Seats Remained in Place

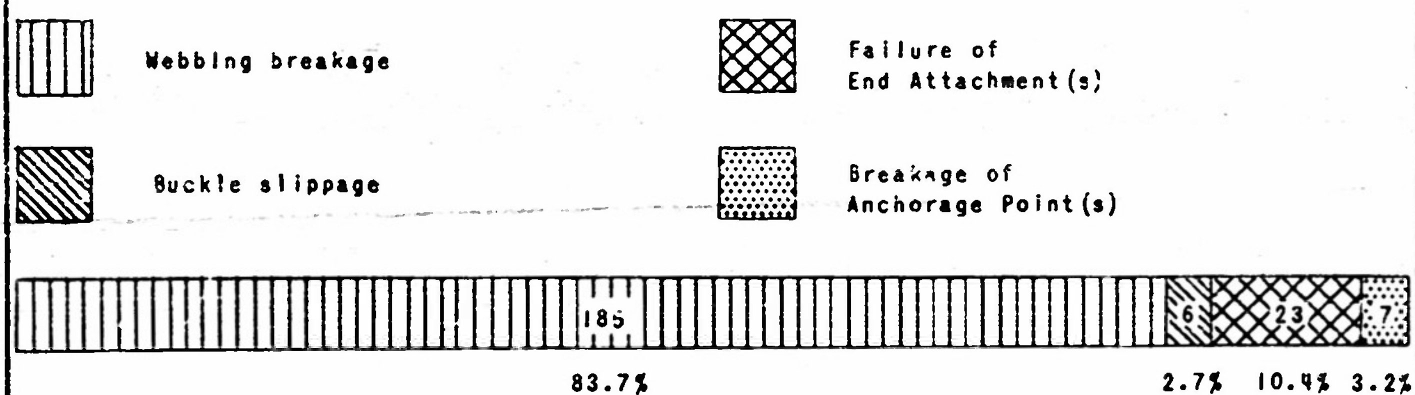

FIGURE 3

SECTION II

ANALYSIS

SECTION II

ANALYSIS

PART I: Relationship between Severe Snubbing Action of Safety Belts and the Occurrence of Intra-Abdominal and Lumbar Spine Injuries.

Discussion of the value of safety belts often has been confused by the belief that severe snubbing action produced "acute flexion of the torso over the safety belt" with consequent intra-abdominal and spinal injury. While Crash Injury Research firmly believes that *jackknifing* rather than flexion commonly takes place in crashes (see Figure 4) the question of the dangerousness of safety belts is only incidentally related to the kinematics of the human body in crashes. The important - and pertinent - question is whether the snubbing action of safety belts (regardless of whether jackknifing *or* flexion takes place) is associated with intra-abdominal and spinal injuries.

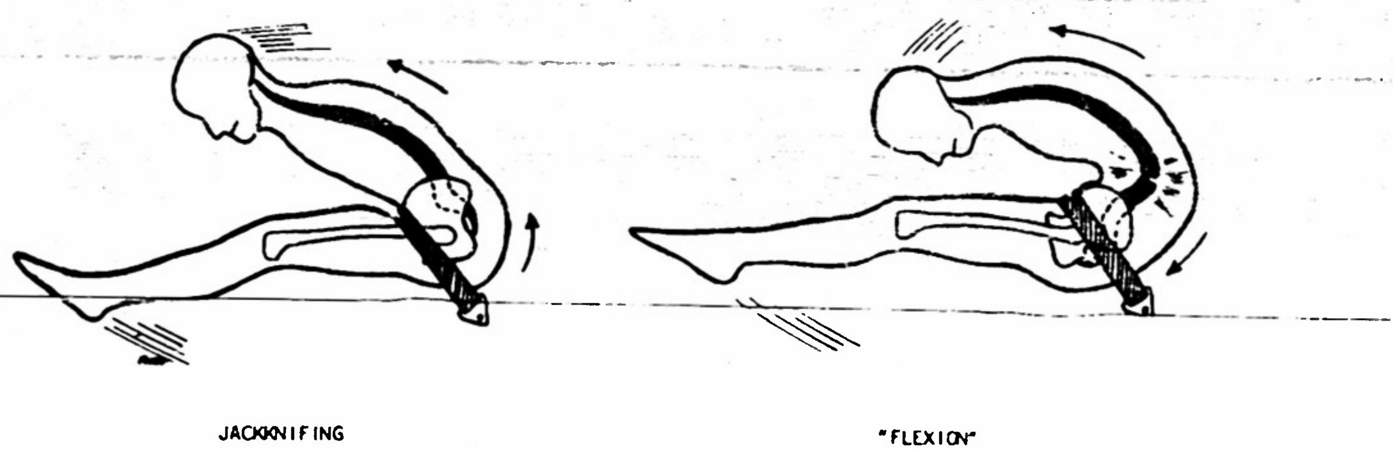

FIGURE 4

Among the 1000 survivors who were *using* safety belts, 240 sustained some injury of the lower torso.[1] Upon examination of these 240 cases we find that there were 116 instances of lumbar spine injury, 33 instances of intra-abdominal injury and 80 instances of bruises, contusions or tenderness of the

[1] FOR DETAILED DATA ON THE TYPES AND NUMBER OF LOWER TORSO INJURIES SUSTAINED, SEE APPENDIX 2.

hips and/or abdomen. These 80 cases give *80 tangible evidences of severe snubbing action by safety belts*, and are used in the comparisons and statistical tests which follow.

Table I, below, records data on the occurrence of intra-abdominal injury both with and without evidence of severe snubbing action.

TABLE I

The Occurrence of Intra-Abdominal Injury in Relation to Severe Snubbing Action by Safety Belts

NUMBER OF SURVIVORS	WITHOUT INTRA-ABDOMINAL INJURY	WITH INTRA-ABDOMINAL INJURY	TOTAL NUMBER OF SURVIVORS USING SAFETY BELTS
WITHOUT EVIDENCE OF SEVERE SNUBBING ACTION	891	29 (3.2%)	920
WITH EVIDENCE OF SEVERE SNUBBING ACTION	76	4 (5.0%)	80
TOTAL	967	33	1000

Table I shows that intra-abdominal injury occurred *without* evidence of severe snubbing action (bruises, contusions, tenderness of hips and/or abdomen) among 3.2% of the survivors. Intra-abdominal injury occurred *with* evidence of snubbing action among 5% of the survivors. Thus, intra-abdominal injuries occur with nearly equal frequency - 3.2% versus 5% - either with or without evidence of severe snubbing action. The slight difference between these two frequencies or percentages was statistically tested (*APPENDIX 3*, test I) and the results of this test confirmed the evidence that *there is no significant correlation between severe snubbing action of safety belts* (as demonstrated by bruises, contusions or tenderness of hips and/or abdomen) *and the occurrence of intra-abdominal injury*.

The same procedure was applied to see whether there was a relationship between severe snubbing action of belts and the occurrence of lumbar spine injuries. Table II shows the occurrence of this type of injury both with and without evidence of severe snubbing action.

TABLE II

The Occurrence of Lumbar Spine Injury in Relation to Severe Snubbing Action By Safety Belts

NUMBER OF SURVIVORS	WITHOUT LUMBAR SPINE INJURY	WITH LUMBAR SPINE INJURY	TOTAL NUMBER OF SURVIVORS USING SAFETY BELTS
WITHOUT EVIDENCE OF SEVERE SNUBBING ACTION	811	109 (11.8%)	920
WITH EVIDENCE OF SEVERE SNUBBING ACTION	73	7 (8.8%)	80
TOTAL	884	116	1000

It will be observed that lumbar spine injuries occurring *without* evidence of severe snubbing action were sustained by 109 out of 920 - 11.8% - of the survivors. Lumbar spine injuries occurring *with* evidence of severe snubbing action was sustained by 7 out of 80 - 8.8% - of the survivors. Thus, lumbar spine injuries occur with nearly equal frequency - there is only a 3% difference - either with or without evidence of severe snubbing action by safety belts. The slight difference between these two frequencies or percentages was statistically tested (*APPENDIX 3*, test 2) and it was found that *there is no significant correlation between the severe snubbing action of safety belts and the occurrence of lumbar spine damage*.

Since neither intra-abdominal nor lumbar spine injuries correlate with severe snubbing action it is clearly suggested that some factor other than the safety belt is responsible for their production. A clue to the nature of this factor would be provided if it were found that intra-abdominal injuries and lumbar spine injuries are *related to each other*. Table III shows the occurrence of lumbar spine injury both with and without the occurrence of intra-abdominal injury.

TABLE III

The Occurrence of Lumbar Spine Injury in Relation to the Occurrence of Intra-Abdominal Injury

NUMBER OF SURVIVORS	WITHOUT LUMBAR SPINE INJURY	WITH LUMBAR SPINE INJURY	TOTAL NUMBER OF SURVIVORS USING SAFETY BELTS
WITHOUT INTRA-ABDOMINAL INJURY	862	105 (10.9%)	967
WITH INTRA-ABDOMINAL INJURY	22	11 (33.3%)	33
TOTAL	884	116	1000

Table III shows that lumbar spine injuries occurred *without* intra-abdominal injuries among 10.9% of the survivors, whereas lumbar spine injuries occurred *with* intra-abdominal injuries among 33.3% of the survivors. This marked difference in the frequency of lumbar spine injuries - a difference of 22.4% - suggests that lumbar spine injuries and intra-abdominal injuries are interrelated. A statistical test (*APPENDIX 3*, test 3) was therefore undertaken to determine the extent to which chance dictated this 22.4% difference. It was found that chance would account for the difference in less than 1 in 1000 cases. Therefore we have statistical evidence that *there is a strong relationship between the incidence of intra-abdominal injuries and the occurrence of lumbar spine injuries*.

Statistical evidence of a relationship between lumbar spine and intra-abdominal injuries is extremely helpful in discovering the cause of these injuries. The next step is to find a factor which is *common to both* types of injury. Examination of the nature of lumbar spine injuries showed that these consist chiefly of *compression* fractures. This implied that severe vertical forces

acted on the spinal column. Later on in this study - in the section which examines the relationship of injuries to principal directions of crash force - it will be seen that both intra-abdominal injuries and lumbar spine injuries are strongly related to vertically acting force. At the present point in the development of this study, however, it was only important to establish that the snubbing action of safety belts was not an important factor in producing intra-abdominal injuries or lumbar spine injuries. Further examination of accident-injury factors such as the use of the belt and its effectiveness, as well as the direction of crash force, must be undertaken to determine causes of these and other torso injuries - as well as injuries in other body areas.

ANALYSIS
(continued)

PART II: Causes of Torso Injury

It has been established by CIR's accident-injury analyses that bruises, contusions and areas of tenderness of the hips and/or abdomen usually are *directly* attributable to safety belts. Among 60 out of 1039 survivors these belt-caused injuries occurred. However, there are many torso injuries sustained in crashes which may be attributed to the belt - *indirectly*. For example, if only a safety belt is used (and the body is not restrained by shoulder harness) the safety belt may cause the torso to jackknife (i.e., hinge at the hips), flail forward and strike objects. In such cases the body may sustain a *direct* injury from the snubbing action of the belt, and simultaneously may sustain injuries *indirectly* attributable to the belt as a result of the pivoting or flailing action. Thus, contusions and puncture wounds of the chest, fractured ribs, intra-thoracic injuries, etc., can be considered as *indirectly* related to the snubbing action of the safety belt - *but not directly attributable to the belt*.

In addition to injuries related directly - or indirectly - to the belt, there are some types of lower torso injury which have no relation to the belt at all; they occur without relationship to snubbing action of the safety belt or to the flailing action which the safety belt induces. Injuries of the buttocks, perineum and genitalia, for example, can be caused by control sticks or by seats deforming and presenting broken, sharp edges. Similarly, puncture wounds and lacerations of the abdomen occasionally are inflicted by broken structures or by push-pull tubes from which control wheels have sheared.

In addition there may be *injuries, such as pelvic, spinal and internal injuries, caused by severe jolt loads transmitted to the body by seats and supporting structures*; these types of injury often occur without any signs of severe snubbing action of the belt (i.e., bruises, contusions or areas of tenderness of hips and/or abdomen) and without evidence in the accident itself that the body was thrown forcibly against any other object or structure.

In examining causes of lower torso injury among 1000 belt-using survivors, there were some injuries for which causes could *not* be readily ascertained.[1] However, these cases were rare - 2.9% of the cases. In most instances there was little difficulty in assigning lower torso injuries to one of three categories:

(1) those caused directly by the belt;

(2) those caused by contact with specific objects and structures;

(3) those caused by jolt loads acting through seats.

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[1] SEE APPENDIX 2 FOR CLASSES AND TYPES OF LOWER TORSO INJURIES ACCORDING TO 'CAUSE'.

Since most causes of injuries could be assigned to these three categories, the percentage of cases in which safety belts were a *direct* cause of lower torso injury could be calculated. For purposes of convenience in the analysis which follows, lower torso injuries caused directly by the belt are referred to as "belt-caused" and injuries caused *either* by objects and structures *or* by jolt loads are referred to as "non-belt-caused".

When the 240 cases of lower torso injuries - including lumbar spine injuries - were tallied, it was found that:

30.4% were "belt-caused";

66.7% were "non-belt-caused";

2.9% were caused by conditions which which could not be reasonably determined.

In summary, the data thus show that the safety belt is a *direct* cause of injury to the *lower torso only*, and that among the 1000 injured safety-belt-wearing survivors there were 240 cases of lower torso injury with 73 - or 30.4% - of these being "belt-caused". Although 30.4% seems to be a considerable proportion, it is significant to note that 64 out of these 73 cases - 87% - consisted only of bruises, contusions or areas of tenderness of hips and/or abdomen. A true assessment of the *dangerousness* of safety belts should be based on serious or critical (dangerous-to-life) injuries which are "belt-caused".

It was found that among the dangerous-to-life, "belt-caused" injuries, 3 were cases of intra-abdominal injury[1] and 6 were cases of lumbar spine injury which had been classified as "belt-caused" on the basis of external evidence of severe snubbing action. Thus, *9 out of 1000* belt-users - or nine/tenths of one percent of the survivors - ***had dangerous lower torso injuries for which the safety belt could reasonably be considered as a direct cause.***

The next step in the assessment of the dangerousness of safety belts was to compare "belt-caused" with "non-belt-caused" dangerous lower torso injuries. Table IV shows the derivation of these percentages.

[1] OF THE 1039 SURVIVORS, 306 - NEARLY 30% - WERE 'SERIOUSLY' OR 'CRITICALLY' INJURED, AND AT LEAST 37 OF THESE SURVIVORS WERE REPORTED TO HAVE DIED SUBSEQUENTLY. IN THESE CASES, CAUSES OF DEATH WERE APPARENT WITHOUT NEED OF AUTOPSY, AND MEDICAL DATA WERE SUFFICIENTLY DETAILED TO CONFIRM AN EXTREMELY LOW INCIDENCE OF INTRA-ABDOMINAL INJURIES.

TABLE IV

The Occurrence of Dangerous Lower Torso Injuries in Relation to "Belt-Cause" and "Non-Belt-Cause"

NUMBER OF SURVIVORS	WITHOUT DANGEROUS LOWER TORSO INJURIES	WITH DANGEROUS LOWER TORSO INJURIES	TOTAL NUMBER OF BELT-WEARING SURVIVORS WITH LOWER TORSO INJURIES
WITH 'BELT-CAUSED' LOWER TORSO INJURIES	64	9 (12.3%)	73
WITH 'NON-BELT-CAUSED' LOWER TORSO INJURIES	72	88 (55.0%)	160
TOTAL	136	97	233

It can be seen in Table IV that a far greater percentage of survivors had "non-belt-caused" dangerous lower torso injuries. A chi-square test examining the difference between the proportions of "belt-caused" and "non-belt-caused" dangerous lower torso injuries (*APPENDIX 3*, test 4) indicated clearly that dangerous injuries of the lower torso are associated with objects and structures or with jolt force transmitted through seats - rather than with the safety belt. The P-value yielded by the test was less than .001, so that the more than 40% difference between the two percentages would occur by chance in less than 1 in 1000 similar instances. It can therefore be predicted on a basis of this test that in survivable lightplane accidents occurring in the future - unless existing conditions are altered - *dangerous injuries of the lower torso will associate with objects and structures or jolt loads through seats* - rather than with safety belts.

Percentages of Survivor-Injury According to Belt Use or Non-Use

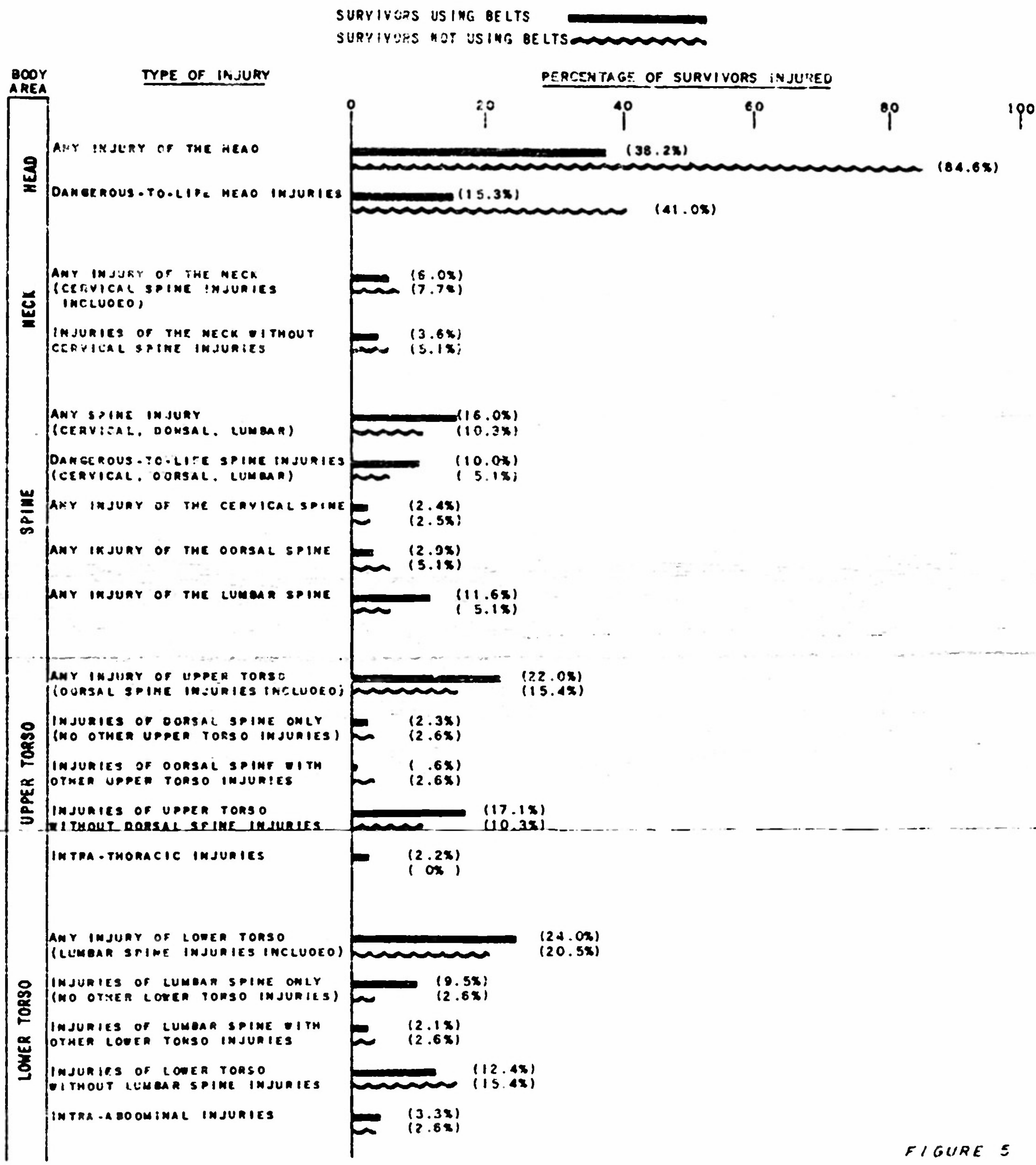

FIGURE 5

ANALYSIS
(continued)

PART III: **Relationship between the Occurrence of Injury and Use or Non-Use of Safety Belts**

As a further basis for evaluation of the performance of safety belts, the frequency of injury of survivors using and not using belts was studied. Of the 1039 survivors whose accident-injury reports were analyzed for this study 1000 used belts and 39 did not. While a sample of 39 might seem to be a small one to use in comparisons, the statistical measures employed herein accord validity to the analytical results obtained from small samples.[1]

To examine injury frequencies when belts were used and were not used, tallies were first made of torso, neck, spine and head injuries among the two groups of survivors. Figure 5 shows how injuries to each of these gross body areas were broken down into sub-categories, and presents the percentage of belt-users and non-users sustaining each category of injury.

It will immediately be noted that *the percentage of torso, neck and spine injuries sustained by both belt users and non-users is similar*; in no instance did the frequency of injury differ by more than 6.9%. This similarity of injury frequency appeared for all categories of injury to the torso, neck and spine. It is notable, however, that there was a wide difference in the frequency of head injury between belt users and non-users, with a remarkably high frequency of head injury when belts were not used.

Chi-square tests (*APPENDIX 3*, tests 5-23) were used to examine all differences between frequencies of injury; these tests showed that *nowhere among the injury categories was there any sign that use of the belt increased the frequency of injuries of the torso, neck or spine*. By contrast, the statistical tests showed that *all types of head damage, as well as dangerous head injuries, are associated with and are increased by non-use of safety belts*. The P-values derived from the two Chi-square tests on head injuries are less than .001, and therefore demonstrate that chance would dictate the differences in injury frequency in less than 1 in 1000 cases. Thus, the increase in head injury frequency is governed by the fact that safety belts were not used. Nevertheless - even though *use of safety belts decreases chances of head injury* - the fact that there were 382 head injuries among 1000 belt-using survivors shows that safety belts *alone* do not give much protection against head injury.

The influence which use or non-use of safety belts has on the occurrence of *any serious or critical injury of the body as a whole* can now be considered. Table V shows the numbers of survivors with serious (5°) and critical (6°) head and body injuries in accordance with belt use or non-use.

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[1] ALL CHI-SQUARE TESTS USED IN THIS STUDY EMPLOY YATES' CORRECTION FOR CONTINUITY. (SEE APPENDIX 3).

TABLE V

The Occurrence of Serious and Critical Injuries
of the Head and Body in Relation to Use or Non-use of Belts

NUMBER OF SURVIVORS	WITHOUT SERIOUS OR CRITICAL HEAD AND BODY INJURIES	WITH SERIOUS OR CRITICAL HEAD AND BODY INJURIES	TOTAL NUMBER OF SURVIVORS
USING SAFETY BELTS	715	285 (28.5%)	1000
NOT USING SAFETY BELTS	18	21 (53.8%)	39
TOTAL	733	306	1039

It will be seen that the percentage of survivors seriously and critically injured when *not* using belts is far greater than the percentage of survivors seriously and critically injured when using belts. The 25.3% difference in the frequency of these dangerous-to-life injuries when belts were not used was analyzed statistically (*APPENDIX 3*, test 24) and it was found that *serious and critical degrees of head and body injury are associated with and increased by not using safety belts*. The P-value here is less than .001, demonstrating that chance dictates the difference in injury frequency in less than 1 in 1000 cases. Thus, an increase in dangerous (serious and critical) head and body injuries is governed by whether or not a safety belt is used, and the inescapable conclusion is reached that *greater overall protection for the head and body from dangerous injuries is provided by the use of safety belts.*

ANALYSIS
(continued)

PART IV: Relationship between the Occurrance of Injury and Failure of Safety Belt Installations

The statistical evidence presented thus far has shown that *the use of safety belts is not dangerous, and affords protection to the body as a whole* - without respect to whether the safety belt installations remained intact or failed. The question therefore arises as to whether injuries are increased by failure of safety belt installations. To test this question, the frequency of injuries among the *722 survivors whose belt installations remained intact* was compared with the frequency of injuries among the *221 survivors whose belt installations failed*. (See Section I for detailed data on types of belt installation failures.) The safety belts involved in this study are mostly of the type with a loop-holding capacity of 2000 pounds, i.e., 1000 pounds in straight tension (see Figure 6).

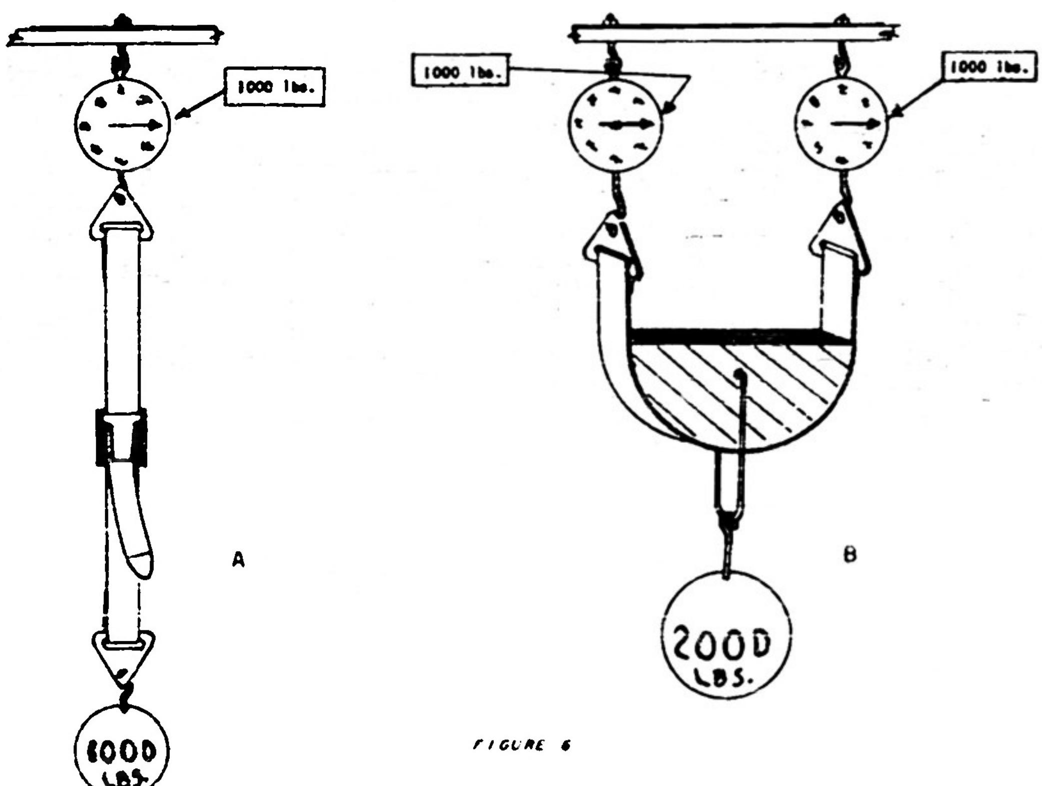

FIGURE 6

A SAFETY BELT CAPABLE OF WITHSTANDING
A 1000 LB. PULL IN STRAIGHT TENSION (A)
WILL HAVE A "LOOP-HOLDING CAPACITY" OF 2000 LBS.
IN A BODY-BLOCK TEST (B)

Percentages of Survivor-Injury According to Belt-Installation Intactness or Failure

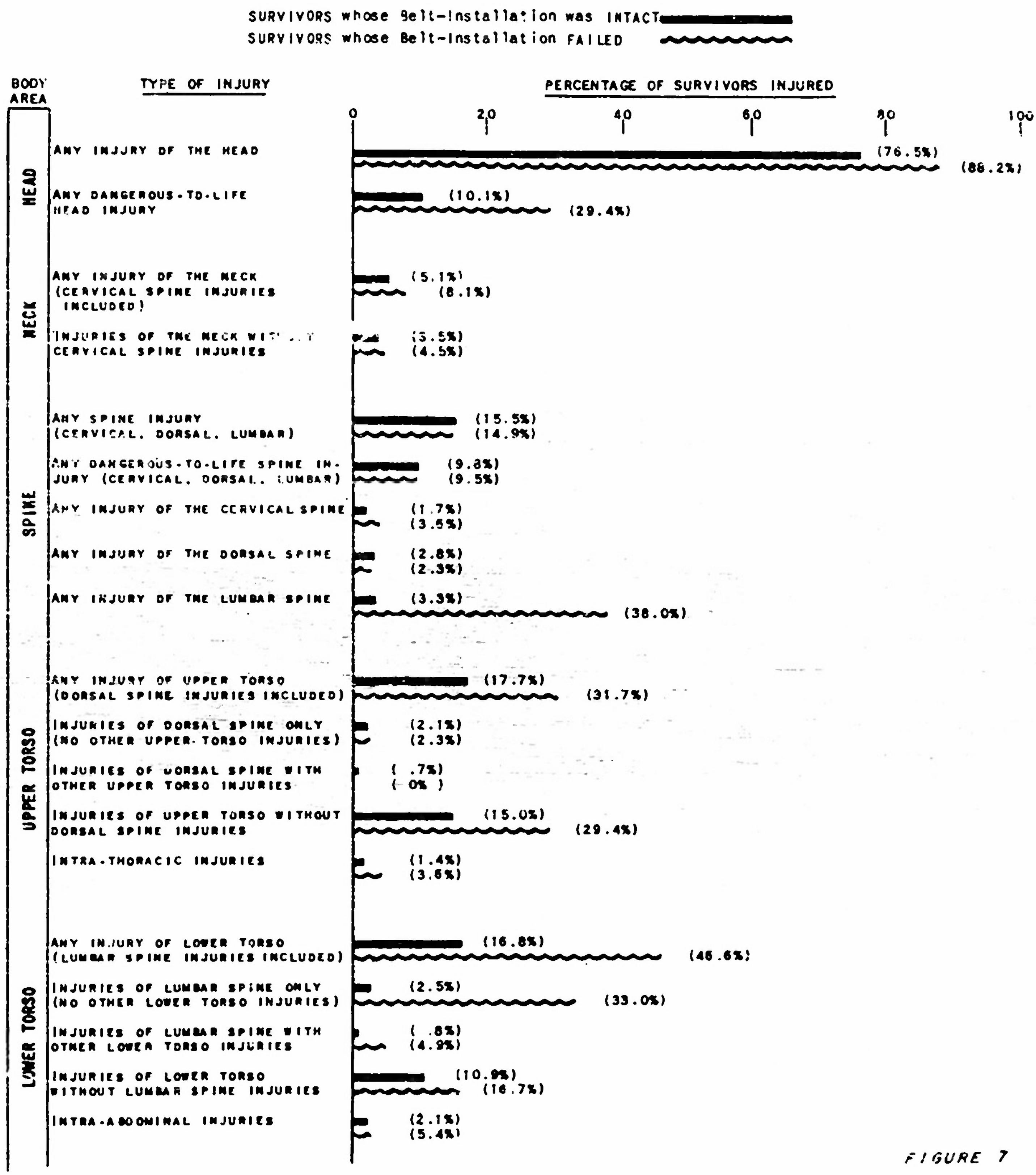

FIGURE 7

Figure 7 shows the frequency with which various classes of torso, neck, spine and head injury occurred, according to whether belt installations remained intact or failed. Inspection of this figure immediately indicates that failure of safety belt installations has a strong influence on changing the overall pattern of survivor injury. Differences in injury frequencies when belt installations remained intact or failed were statistically examined (APPENDIX 3, tests 26-43), and it was found that while certain injury categories are not affected by safety belt installation failures, there are important categories which are significantly related to this variable. In particular, it was shown that:

(1) Injuries of the upper and the lower torso - with or without injuries of the spine - are associated with and increased by failure of safety belt installations.

(2) The occurrence of neck and/or cervical spine injuries is not related to failure of belt installations.

(3) Frequencies of injury to the dorsal spine are similar whether belt installations fail or remain intact, but injuries of the lumbar spine increase when belt installations fail.

(4) Intra-abdominal injuries are associated with and increased by belt installation failure.

(5) Intra-thoracic injuries tend to associate with belt installation failure.

(6) Head damages of all degrees, as well as dangerous degrees of head injury, increase with the failure of safety belt installations.

The effect which failure of safety belt installations has on the occurrence of serious (5°) and critical (6°) injuries of the head and body was next examined. Table VI shows the number of survivors with serious and critical head and body injuries in relation to failure of safety belt installations.

TABLE VI

The Occurrence of Serious and Critical Injuries of the Head and Body in Relation to Effectiveness of Safety Belt Installations

NUMBER OF SURVIVORS	WITHOUT SERIOUS OR CRITICAL HEAD AND BODY INJURIES	WITH SERIOUS OR CRITICAL HEAD AND BODY INJURIES	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATIONS REMAINED INTACT	556	166 (23.0%)	722
WHOSE BELT INSTALLATIONS FAILED	133	88 (39.8%)	221
TOTAL	689	254	943 *

* Although there were 1000 belt-using survivors, data on 57 are not used here; in these 57 cases, seats pulled free, so that effectiveness of safety belt installations was uncertain.

It will be seen that 23.0% of accident survivors sustained serious or critical (dangerous-to-life) head and body injuries when their belt installations were effective; on the other hand, 39.8% of the survivors whose belt installations failed sustained dangerous-to-life head and body injuries. A statistical test (*APPENDIX 3*, test 44) confirmed the indication that *serious and critical injuries of the head and body are associated with and increased by failure of safety belt installations.*

The statistical evidence from this and previous tests show beyond a doubt that *effectiveness of safety belt installations provides protection in accidents; failure of safety belt installations significantly increases exposure to dangerous crash injuries.*

* * * * * * * * *

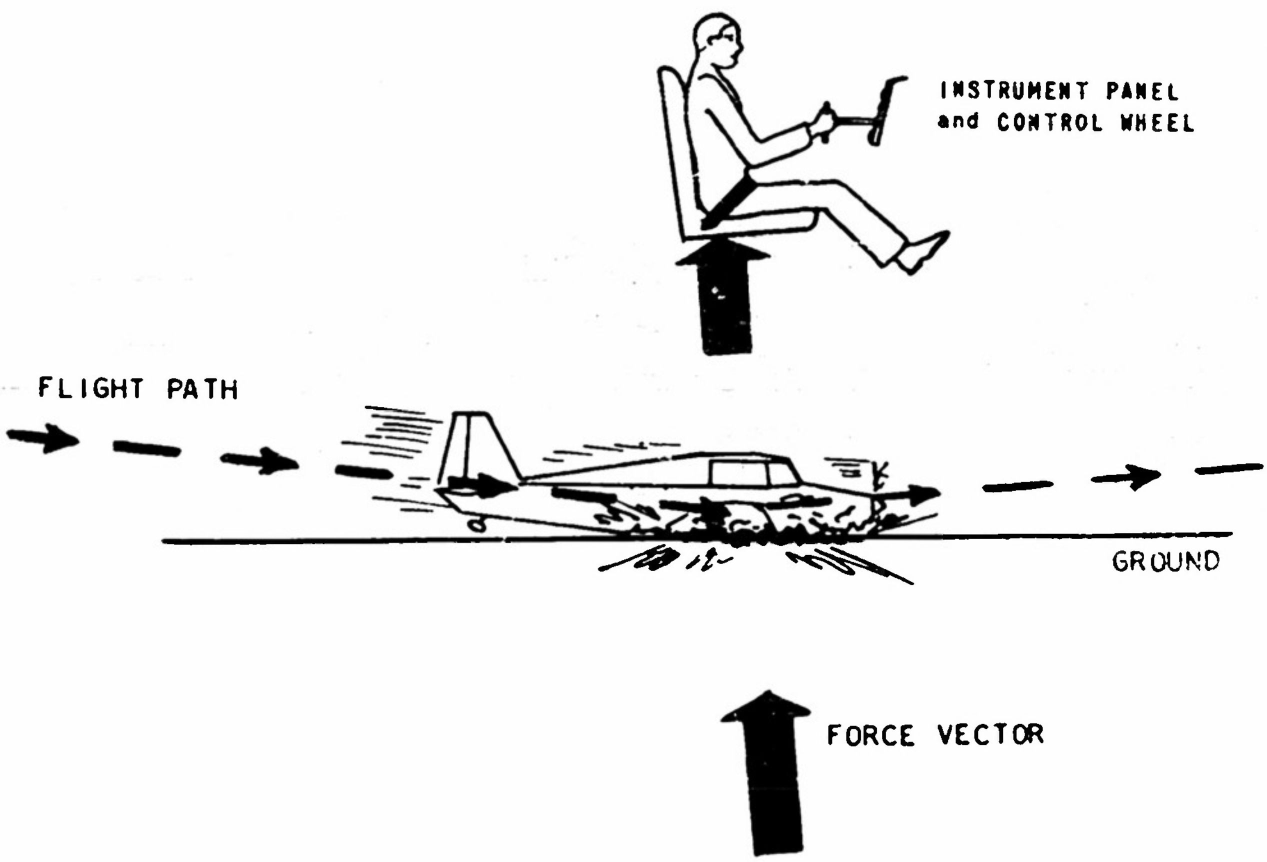

FIGURE 8: "FLAT" - RICOCHETING - ACCIDENT: PRODUCES VERTICALLY ACTING FORCES ON AIRCRAFT SEATS AND OCCUPANTS.

ANALYSIS
(continued)

PART V: Relationship between the Occurrence of Injury and Principal Direction in which Crash Force Acts

It has been previously noted that there were many cases of injury among the survivors which could not be attributed to either the safety belt or to any specific object or structure. In these cases, the survivors had sustained intra-abdominal and/or spinal injuries, but had no evidence of any external bruises, contusions or areas of tenderness which could be traced to structure or to the snubbing action of the safety belt as causative factors. Significantly, it was found (see Section II, Part I) that the occurrence of intra-abdominal injuries is associated with the occurrence of lumbar spine injuries. It was therefore considered likely that some other factor - not previously examined - accounted for the occurrence of these injuries.

Since a large proportion of torso injuries were *compression* fractures of the dorsal and lumbar spines, it was suspected that forces acting vertically through the seats might be responsible for these - and other types - of injuries. To test this assumption it was necessary to make comparisons between the frequency of injuries in the presence of forces acting vertically through the seats and of those occurring when "longitudinally" acting forces were present.

It is, of course, common knowledge that decelerative forces acting during a crash are multiple in direction. There is, however, generally a *principal* force which exceeds all the other forces in magnitude, and which determines the resultant or vector. For example, let us assume that a plane makes a crash landing with the nose almost level (see Figure 8). The force acting vertically through the floor and seats is far greater than the longitudinal force opposing the forward movement of the plane. Also, should the plane crash with one wing low, a lateral component of force might be introduced, but this force probably would be exceeded by the vertically acting force. The direction of force in this crash would therefore be considered to be *principally vertical*.

In extracting cases for comparison, those in which the principal force acted chiefly in a vertical direction through the seats were placed in one group. There were 116 survivors in crashes of this type. Cases in which the principal resultant or vector force was nearly parallel to the longitudinal axis of the plane were put in another - *principally longitudinal* force group - (see Figure 9). There were 580 survivors in accidents where the force was principally longitudinal.

If direction of crash force is a definite injury-producing factor, it might be expected that the head would be more frequently injured in accidents which involve crash forces acting principally in a "longitudinal" direction - since longitudinal force implies that the head will continue its forward "line of flight" and come into forcible contact with objects and structures. To test this assumption the number of survivors sustaining head injury was obtained

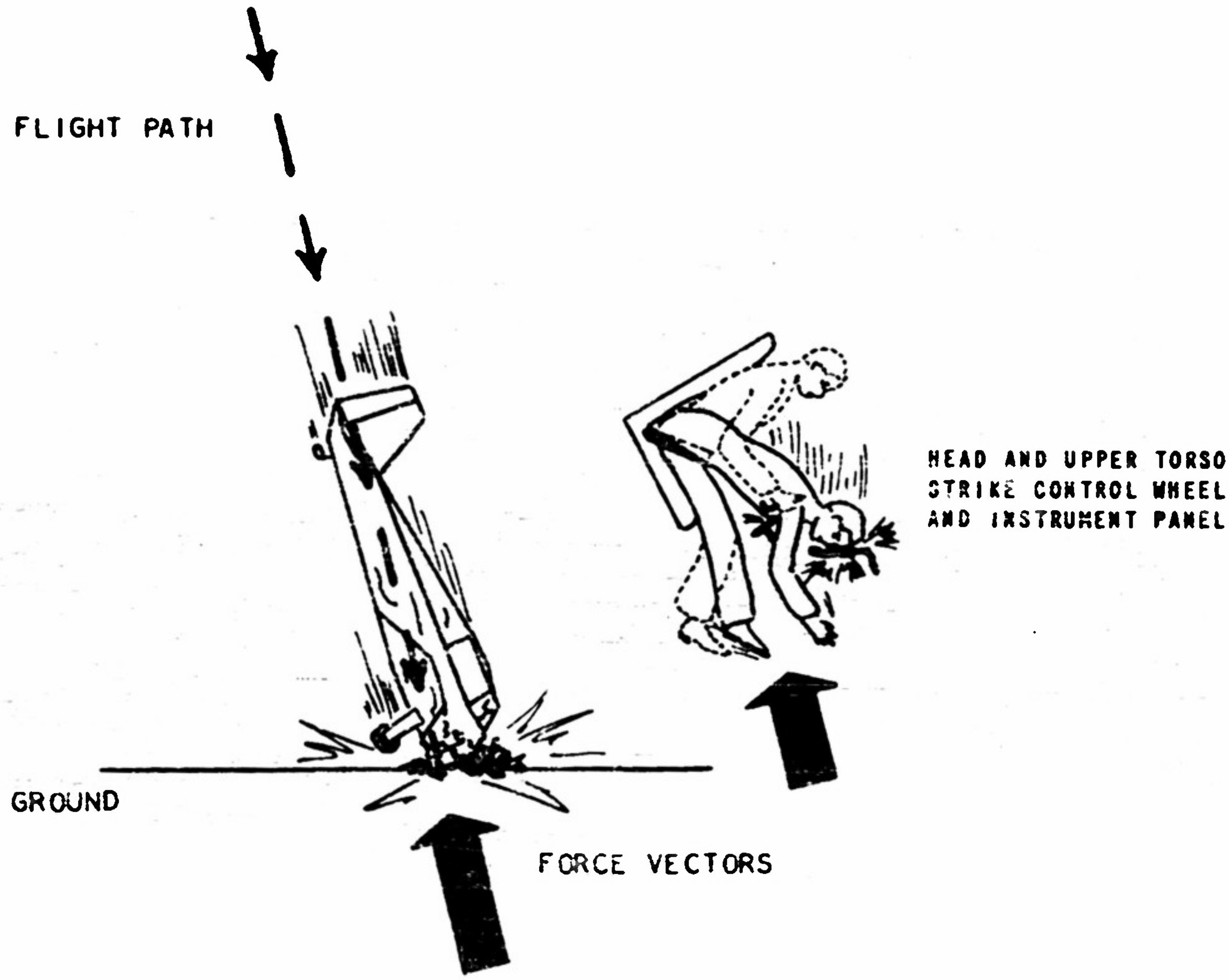

FIGURE 9: "HIGH ANGLE" ACCIDENT:
PRODUCES LONGITUDINALLY ACTING FORCES ON
AIRCRAFT SEATS AND OCCUPANTS.

from each of the two groups. Table VII shows the frequency of *all* degrees of head damage; Table VIII shows the frequency of *serious and critical* degrees of head injury, with respect to directions of crash force.

TABLE VII

The Occurrence of Head Damage in Relation to Principal Directions of Crash Force

NUMBER OF SURVIVORS	WITHOUT HEAD DAMAGE	WITH HEAD DAMAGE	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	95	485 (83.6%)	580
IN 'VERTICAL FORCE' CRASHES	30	86 (74.1%)	116
TOTAL	125	571	696

TABLE VIII

The Occurrence of Serious and Critical Head Injuries in Relation to Principal Directions of Crash Force

NUMBER OF SURVIVORS	WITHOUT SERIOUS OR CRITICAL HEAD INJURIES	WITH SERIOUS OR CRITICAL HEAD INJURIES	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	475	105 (18.1%)	580
IN 'VERTICAL FORCE' CRASHES	104	12 (10.3%)	116
TOTAL	579	117	696

Examination of Tables VII and VIII shows that the frequency of all degrees of head damage, as well as serious and critical (dangerous-to-life) injuries of the head, is *less* in crashes involving principally vertical force. The suggestion is definite that the occurrence of head injuries *decreases* under conditions of vertical crash force. This suggestion was statistically tested (*APPENDIX 3,* tests 45 and 46) and it was found that *injuries of the head, including dangerous-to-life head injuries, are significantly decreased when the direction of crash force is principally vertical*. Thus, the converse is also true: *head injuries are increased when the direction of crash force is principally longitudinal*, and we find valid statistical evidence demonstrating that direction of crash force is a significant factor in the production of injury. It is therefore desirable to observe whether direction of crash force has any association with *serious and critical* injuries of the head and body. Table IX shows the number of survivors in each direction of force group sustaining these dangerous-to-life injuries.

Percentages of Survivor-Injury According to Principal Directions of Crash Force

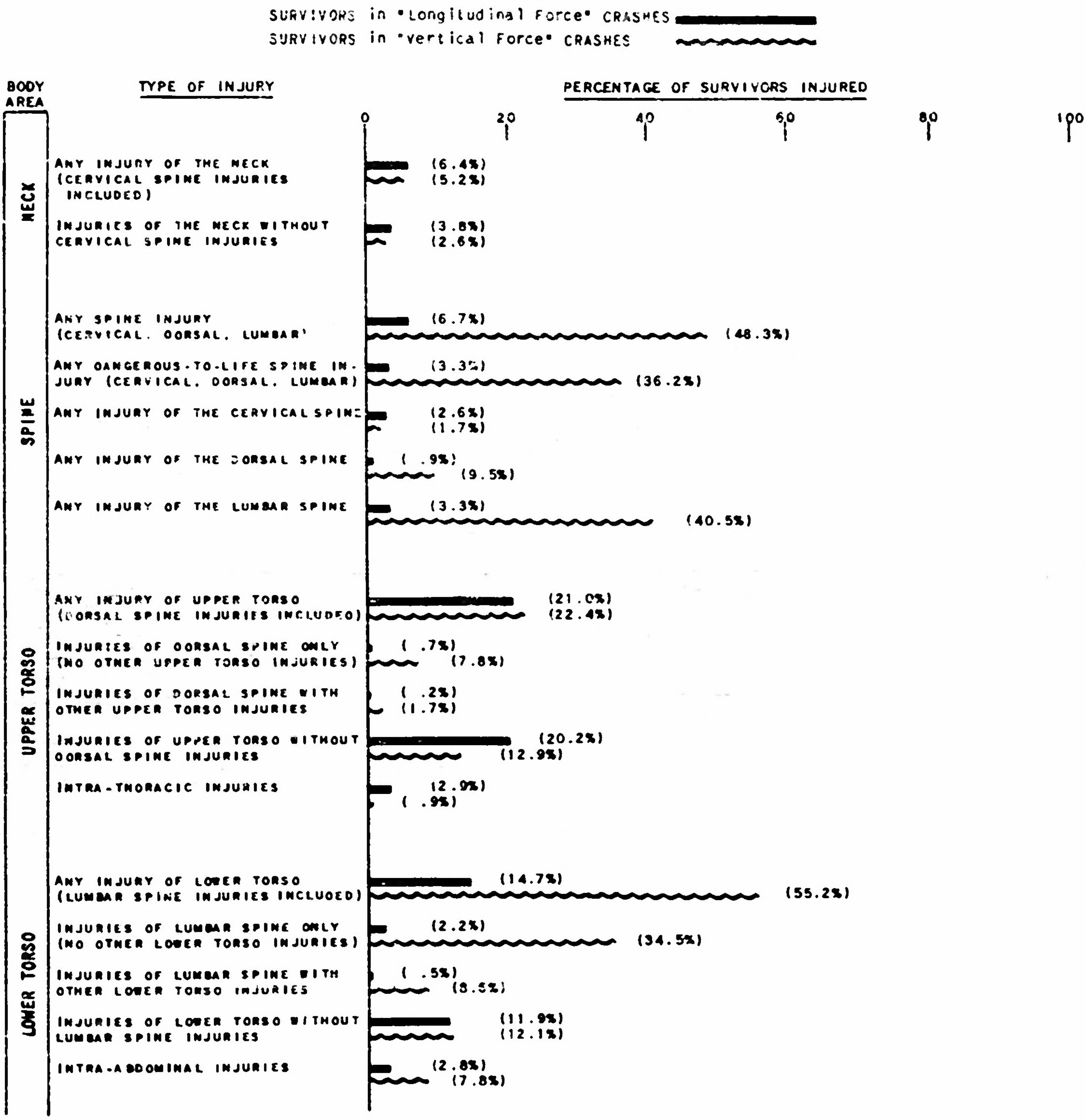

FIGURE 10

TABLE IX The Occurrence of Serious and Critical Injuries of the Head and Body in Relation to Principal Directions of Crash Force			
NUMBER OF SURVIVORS	WITHOUT SERIOUS OR CRITICAL HEAD AND BODY INJURIES	WITH SERIOUS OR CRITICAL HEAD AND BODY INJURIES	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	430	150 (25.9%)	580
IN 'VERTICAL FORCE' CRASHES	57	59 (50.9%)	116
TOTAL	487	209	696

It will be observed that 150 out of 580 (25.9%) of the survivors in crashes involving longitudinal force sustained serious and critical injuries; 59 out of 116 (50.9%) of the survivors in crashes involving vertical force sustained serious and critical injuries. This increase of 25% clearly suggests that serious and critical head and body injuries are increased when the crash force is principally vertical. The Chi-square test (*APPENDIX 3*, test #7) proves that *serious and critical injuries of the head and body are associated with and increased by principally vertical crash force*. This finding must be viewed with some caution: it should not be interpreted to mean that "vertical force" crashes as a class are more dangerous than "longitudinal force" crashes. A large number of "vertical force" crashes are so minor in nature that no injuries are sustained - so that these crashes are not reported to CIR for inclusion in accident-injury studies.

As the statistical evidence demonstrates that "vertical force" is a distinct factor in endangering the body in crashes, it would be desirable to determine which specific classes of injury are associated with this force. Figure 10 shows the percentages of survivors sustaining varying categories of torso, neck and spine injuries when crash forces acted in a principally vertical or in a principally longitudinal direction.

When the differences in frequency of injury are analyzed (tests #8-64), it is found that *vertically acting force is a significant factor relative to certain categories of injury*; the occurrence of the following injuries was found to *increase* in the presence of principally vertical crash forces:

1. Dangerous-to-life injuries of the spine as a unit;
2. All types of lumbar spine injuries;
3. All types of dorsal spine injuries;
4. Intra-abdominal injuries.

The importance of these statistical findings on direction of crash force as a factor in the occurrence of injury cannot be overestimated. The findings strongly suggest a need for developing structures which will absorb and cushion vertically acting crash forces. This might be achieved through design of landing gear (with energy-absorbing rather than abrupt collapse characteristics) integrated with improved design of energy absorbing structures in the hull, floor and seats. Efforts in this direction could effectively reduce exposure to injuries of the dorsal and lumbar spines, as well as the chances of sustaining intra-abdominal injuries.

SECTION III

SUMMARY
and
RECOMMENDATIONS

SECTION III

SUMMARY AND RECOMMENDATIONS

The concept that lap-type safety belts used in civil aircraft are dangerous and frequently cause injuries is not supported by the results of this statistical study. A consistent, coherent and logical body of evidence - drawn from statistical analyses of accident and injury data from severe but survivable lightplane crashes - shows that (1) safety belts are a very infrequent cause of injury and are not "dangerous"; (2) safety belts provide protection for the body in crashes, and (3) injuries which may have seemed directly related to safety belts actually are determined by other factors such as failure of safety belt installations and "vertically acting" crash forces. These conclusions are based on the following major findings:

1. Nearly 82% of *torso* injuries are not caused directly by the safety belt. Of the 73 injuries among 1000 survivors which were directly attributable to safety belts, 64 - 87% - consisted of injuries of a minor nature: bruises, contusions or tenderness of the hips and/or abdomen.

2. Severe snubbing action of safety belts - as evidenced by 80 instances of bruises, contusions or tenderness of hips and/or abdomen - does not correlate significantly with the occurrence of intra-abdominal injuries or lumbar spine injuries. However, these two types of injury are related to each other, for the occurrence of intra-abdominal injuries is associated with and increased by the occurrence of lumbar spine injuries.

3. Serious and critical (dangerous-to-life) injuries of the lower torso - intra-abdominal injuries and compression fractures of the first two lumbar vertebrae - are related either to objects, structures or the transmittal of vertically acting forces, rather than to the safety belt.

4. The frequency of injury to the neck, torso and spine is similar when safety belts are used or are not used, whereas the frequency of all degrees of head injuries - including dangerous-to-life head injuries - is associated with and increased by non-use of safety belts. Non-use of safety belts also significantly increases the chances of sustaining any serious or critical (dangerous-to-life) injury of the head or body.

5. Injuries of the upper and the lower torso are associated with and increased by failure of safety belt installations.

6. Injuries of the lumbar spine and intra-abdominal injuries are associated with and increased by failure of safety belt installations.

7. Belt installation failures increase the occurrence of all types of head damage, including serious and critical degrees of damage.

8. The chances of sustaining any serious or critical (dangerous-to-life) injury of the head or body are increased significantly when safety belt installations fail.

9. Head injuries, although decreased by the use of safety belts, are significantly associated with and increased by principally "longitudinal" crash forces.

10. Serious and critical (dangerous-to-life) injuries of the head and body are associated with and increased by principally "vertical" crash forces. Principally "vertical" crash forces are a significant factor in the production of dangerous-to-life spine injuries, all types of dorsal and lumbar spine damages, and intra-abdominal injuries.

RECOMMENDATIONS

1. Provide safety belt installations (webbing, hardware, carry-through and anchorage points) which will hold occupants in place under conditions of crash force which leave cockpit and cabin structures reasonably intact.

2. For increased protection in aircraft crashes, passengers should wear their safety belts.

3. Shoulder harness should be worn to prevent forcible contact of the head and upper torso with structures or objects having dangerous injury potentials.

4. Engineering effort should be applied to designing landing gear, fuselage, floor and seat structures to progressively absorb vertically acting crash force.

Decelerations in many lightplane accidents studied by Crash Injury Research loaded standard 2-inch safety belts up to - and beyond - their ultimate design strength. Decelerations of 20 to 30g were computed from impact velocities and stopping distances of the aircraft. Twenty-two percent of safety belts (the majority with a loop-holding capacity of 2000 lbs.) failed; nine-tenths of one percent of survivors sustained dangerous injuries from the snubbing action of safety belts. The severity of such crash decelerations, and the low frequency of safety-belt injuries, suggest that the conclusions in this report are applicable to similar safety belts under conditions of severe crash deceleration in large transport type aircraft.

CIR's computations of the magnitude of crash decelerations in small planes have been confirmed unofficially by preliminary data from controlled crash tests of lightplanes conducted by the National Advisory Committee for Aeronautics. In these NACA tests, mean decelerations of 25g occurred for .05 seconds, with peak loads between 30 and 35g for .02 seconds.

SECTION IV

APPENDICES

APPENDIX I

THE SCOPE OF THE STUDY AND THE SELECTION OF CASES

1. Sources of Crash Injury Research Data

Accident data used in this study were extracted from accident reports completed and forwarded to Crash Injury Research by accident investigators of the Civil Aeronautics Board, State Aeronautics Commissions and State Police organizations. Completed CIR accident-injury reports include photographs of general wreckage, the crash scene, cockpit and cabin interiors, seats, seat attachments, control wheels and other objects which may have caused injury. Medical data is based on reports by physicians and medical officers having charge of injured persons. These CIR medical reports request specific statements with respect to bruises of the hips and abdomen from safety belts, evidence of internal injuries (abdominal and thoracic), chest injuries caused by control wheels, and periods of unconsciousness with related evidence of concussion.

2. General Nature of the Accidents Supplying Data

The crashes furnishing material for this study occurred in civilian and surplus military aircraft having a gross weight of 1000 to 3500 pounds. The accidents for the most part represent run-of-the-mill *survivable* crashes in private flying with impact velocities ranging up to 100 mph. Included are stall-spin accidents, vertical or high-angle collisions with the ground, impact with the ground following collisions with trees or high tension wires, cartwheeling accidents, low-angle accidents such as flying into snow covered ground, belly landings, and other accidents incident to take-off, flight and landing.

Impact velocities and stopping distances in hundreds of severe lightplane crashes analyzed by Crash Injury Research suggested that survivors had been exposed to average decelerations in the order of 25g. Preliminary data from three controlled lightplane crash tests conducted by the National Advisory Committee for Aeronautics apparently substantiate Crash Injury Research computations: these NACA data indicate that 50 mph spin-stall type crashes of lightplanes produced decelerations in the order of 25 to 30g for approximately .05 seconds with rates of onset up to 1500g per second - without extensive collapse of cabin structures.

3. Elimination of Data Not Pertinent to the Study

Eliminations were made from case records on 1258 persons in CIR files. These eliminations were made as follows:

Fatalities: Records on persons killed in accidents were omitted from the study

since complete autopsiss are rarely performed on civilians who are killed in, or die shortly after, aircraft accidents. Consequently, the validity of post-mortem data on fatally injured persons is often in doubt, particularly with regard to injuries of the spine, brain lesions, and other internal damage.

"Minor" and "Extreme" Accidents: Records on persons involved in accidents classified by CIR as "minor" or "extreme" in nature were eliminated. Accidents termed "minor" are such that there is virtually no damage to the aircraft and the degree of force involved is relatively negligible. Usually in "minor" accidents there is no significant exposure to injury. Accidents on the other end of the accident-severity scale - "extreme" accidents - often are so severe as to involve virtual disintegration of both aircraft and occupants, so that data is not useful for studying causes of injury. The cases remaining for study consisted, therefore, of "survivable" accidents - ranging in severity from "moderate" to "extremely severe" - in which cockpit or cabin structures remained substantially intact.

Inadequate Evidence: Elimination of cases was made when safety belts had been burned, or when other evidence which might be helpful in determining injury causes was destroyed. Also, cases which were not completely reported, either in accident or medical details, were eliminated.

The above eliminations left 1064 cases of survivors for study. From these were eliminated the records of 25 survivors in whose cases it was uncertain whether or not belts had been worn, or where shoulder harness had been used.

The actual cases retained for study were 1039 in number. The 1039 survivors were involved in 670 crashes, and of these 1039 survivors 1000 had used their safety belts, and 39 had not.

For convenience in tallying, the 1039 case records were divided into four almost equal sample groups. The method used in establishing these sample groups was identical with that prescribed by statisticians for CIR's report "The Site, Frequency and Dangerousness of Injury Sustained by 800 Survivors of Lightplane Accidents". The 1039 cards representing 1039 survivors were sorted into 10 piles, each of which represented the final digit of the assigned case number. These 10 piles were then dealt out in sequence into four approximately equal groups. During the course of the study, when various tallies were made, it was found - as had been expected from experience with the above-named report - that each of the four samples in many respects resembled one another. There is some suggestion that data such as that explored in this report might in the future be based on one small sample which is representative of the larger group of cases on file.

APPENDIX 2

INJURY DATA

1. All Degrees of Body Injury

	NUMBER OF SURVIVORS WITH:	1000 USERS OF BELTS	39 NON-USERS OF BELTS	TOTAL SURVIVORS
HEAD	ANY INJURY INVOLVING THE HEAD	797	34	831
NECK	ANY INJURY OF THE NECK (CERV.SPINE INJ. INCLUDED)	60	3	63
	INJURIES OF THE NECK WITHOUT CERVICAL SPINE INJURY	36	2	38
UPPER TORSO	ANY INJURY OF THE UPPER TORSO (DORS.SPINE INJ.INCLUDED)	200	6	206
	INJURIES OF DORSAL SPINE ONLY (NO OTHER U.TORS.INJURIES)	23	1	24
	INJURIES OF DORSAL SPINE WITH OTHER U.TORSO INJURIES	6	1	7
	INJURIES OF UPPER TORSO WITHOUT DORSAL SPINE INJURIES	171	4	175
LOWER TORSO	ANY INJURY OF THE LOWER TORSO (LUMB.SPINE INJ. INCLUDED)	240	8	248
	INJURIES OF LUMBAR SPINE ONLY (NO OTHER L.TORSO INJURIES)	95	1	96
	INJURIES OF LUMBAR SPINE WITH OTHER L.TORSO INJURIES	21	1	22
	INJURIES OF LOWER TORSO WITHOUT LUMBAR SPINE INJURIES	124	6	130
EXTREMIT.	ANY INJURY INVOLVING 1 OR MORE OF THE ARMS OR LEGS	590	24	614
SPINE	ANY SPINE INJURY (CERVICAL, DORSAL OR LUMBAR	160	4	164
	ANY INJURY OF THE LUMBAR SPINE	116	2	118
	ANY INJURY OF THE DORSAL SPINE	29	2	31
	ANY INJURY OF THE CERVICAL SPINE	24	1	25

2. Dangerous Degrees of Body Injury

	NUMBER OF SURVIVORS WITH:	1000 USERS OF BELTS	39 NON-USERS OF BELTS	TOTAL SURVIVORS
HEAD	DANGEROUS HEAD INJURIES (SKULL FRACTURES, BRAIN LESIONS, ETC.)	153	16	169
UPPER TORSO	INTRA-THORACIC INJURIES	22	0	22
LOWER TORSO	INTRA-ABDOMINAL INJURIES	33	1	54
SPINE	ANY DANGEROUS SPINE INJURY	100	2	102
ENTIRE BODY	ANY DANGEROUS INJURY IN ANY VITAL BODY AREA	285	21	306

APPENDIX 2

(continued)

3. Causes of Lower Torso Injury Among 1000 Belt-Users

NUMBER OF SURVIVORS WITH:	INJURY CAUSED BY			
	BELT	CONTACT WITH OBJECT OR BY TRANSMITTAL OF FORCE	UNKNOWN	TOTAL
ANY INJURY OF THE LOWER TORSO (L.SP.INJ.INCLUDED)	73	160	7	240
INJURIES OF THE LUMBAR SPINE ONLY (NO OTHER INJURY)	0	95	0	95
INJURIES OF THE LUMBAR SPINE WITH OTHER L.TORSO INJ.	8	11	2	21
INJURIES OF LOWER TORSO WITHOUT LUMB.SPINE INJURIES	65	54	5	124
INJURIES TO THE BUTTOCKS, PERINEUM, GENITALIA	0	27	0	27
INJURIES TO THE PELVIC BONES AND/OR ARTICULATIONS	0	30	0	30
EXTERNAL INJURY, HIPS AND/OR ABDOMEN	64	15	1	80
INTRA-ABDOMINAL INJURY	3	24	6	33

APPENDIX 3

STATISTICAL TESTS

The analyses used in this study are based on Chi-square tests[1]. Repeated Chi-square tests on the same data must be viewed with some caution. Since the significance level used here would lead to errors once in 20 times under the Null Hypothesis, and since there are 64 Chi-squares used, a few of the significant results might be misleading. However, a notable feature of the data for this report is the consistent, logical and coherent pattern of evidence. Because of this pattern, the whole of the Chi-square evidence is stronger than its individual parts.

Tests 1 and 2

SEVERE SNUBBING ACTION OF SAFETY BELTS

Test 1

The Occurrence of Intra-Abdominal Injury in Relation to Severe Snubbing Action By Safety Belts

NUMBER OF SURVIVORS	WITHOUT INTRA-ABDOMINAL INJURY	WITH INTRA-ABDOMINAL INJURY	TOTAL NUMBER OF SURVIVORS USING SAFETY BELTS
WITHOUT EVIDENCE OF SEVERE SNUBBING ACTION BY BELTS	891	29 (3.2%)	920
WITH EVIDENCE OF SEVERE SNUBBING ACTION BY BELTS	76	4 (5.0%)	80
TOTAL	967	33	1000

DIFFERENCE + 1.8%
CHI-SQUARE .34
P-VALUE .56

Test 2

The Occurrence of Lumbar Spine Injury in Relation to Severe Snubbing Action by Safety Belts

NUMBER OF SURVIVORS	WITHOUT LUMBAR SPINE INJURY	WITH LUMBAR SPINE INJURY	TOTAL NUMBER OF SURVIVORS USING SAFETY BELTS
WITHOUT EVIDENCE OF SEVERE SNUBBING ACTION BY BELTS	811	109 (11.8%)	920
WITH EVIDENCE OF SEVERE SNUBBING ACTION BY BELTS	73	7 (8.8%)	80
TOTAL	884	116	1000

DIFFERENCE − 3.0%
CHI-SQUARE .397
P-VALUE .53

[1]YATES'S CORRECTION FOR CONTINUITY WAS USED IN ALL CHI-SQUARE CALCULATIONS.

Test 3

The Occurrence of Lumbar Spine Injury in Relation to the Occurrence of Intra-Abdominal Injury

NUMBER OF SURVIVORS	WITHOUT LUMBAR SPINE INJURY	WITH LUMBAR SPINE INJURY	TOTAL NUMBER OF SURVIVORS USING SAFETY BELTS
WITHOUT INTRA-ABDOMINAL INJURY	862	105 (10.9%)	967
WITH INTRA-ABDOMINAL INJURY	22	11 (33.3%)	33
TOTAL	884	116	1000

DIFFERENCE + 22.4%
CHI-SQUARE 13.76
P-VALUE < .001

Test 4

The Occurrence of Dangerous Lower Torso Injury in Relationship to "Belt-Cause" and "Non-Belt-Cause"

NUMBER OF SURVIVORS	WITH NO DANGEROUS LOWER TORSO INJURY	WITH DANGEROUS LOWER TORSO INJURY	TOTAL NUMBER OF SURVIVORS
WITH INJURIES CAUSED BY THE BELT	64	9 (12.3%)	73
WITH INJURIES CAUSED BY OBJECTS AND STRUCTURES OR BY TRANSMITTAL OF FORCE	72	88 (55.0%)	160
TOTAL	136	97	233

DIFFERENCE + 42.7%
CHI-SQUARE 36.006
P-VALUE < .001

Tests 5 - 24

RELATIONSHIP BETWEEN THE OCCURRENCE OF INJURY AND THE USE OR NON-USE OF SAFETY BELTS

Test 5

Any Injury of the Lower Torso, Lumbar Spine Injuries Included

NUMBER OF SURVIVORS	WITHOUT LOWER TORSO INJURY	WITH LOWER TORSO INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	760	240 (24.0%)	1000
NOT USING BELTS	31	8 (20.5%)	39
TOTAL	791	248	1039

DIFFERENCE − 3.5%
CHI-SQUARE .095
P-VALUE .75

Test 6

Injuries of the Lumbar Spine Only (no other lower torso injuries)

NUMBER OF SURVIVORS	WITH NO LUMBAR SPINE INJURY	WITH LUMBAR SPINE INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	905	95 (9.5%)	1000
NOT USING BELTS	38	1 (2.6%)	39
TOTAL	943	96	1039

DIFFERENCE − 6.9%
CHI-SQUARE 1.68
P-VALUE .19

Test 7

Injuries of the Lumbar Spine With Other Lower Torso Injuries

NUMBER OF SURVIVORS	WITHOUT LUMBAR SPINE INJURY	WITH LUMBAR SPINE INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	979	21 (2.1%)	1000
NOT USING BELTS	38	1 (2.6%)	39
TOTAL	1017	22	1039

DIFFERENCE + .5%
CHI-SQUARE 0
P-VALUE 1.0

Test 8

Injuries of the Lower Torso Without Lumbar Spine Injuries

NUMBER OF SURVIVORS	WITHOUT LOWER TORSO INJURY	WITH LOWER TORSO INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	875	124 (12.4%)	1000
NOT USING BELTS	33	6 (15.4%)	39
TOTAL	909	130	1039

DIFFERENCE + 3.0%
CHI-SQUARE .12
P-VALUE .73

Test 9

Intra-Abdominal Injuries

NUMBER OF SURVIVORS	WITHOUT INTRA-ABDOMINAL INJURY	WITH INTRA-ABDOMINAL INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	967	33 (3.3%)	1000
NOT USING BELTS	38	1 (2.6%)	39
TOTAL	1005	34	1039

DIFFERENCE - .7%
CHI-SQUARE 0
P-VALUE 1.0

Test 10

Any Injury of the Upper Torso, Dorsal Spine Injuries Included

NUMBER OF SURVIVORS	WITHOUT UPPER TORSO INJURY	WITH UPPER TORSO INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	780	220 (22.0%)	1000
NOT USING BELTS	33	6 (15.4%)	39
TOTAL	813	226	1039

DIFFERENCE - 6.6%
CHI-SQUARE .68
P-VALUE .41

Test 11

Injuries of the Dorsal Spine Only
(no other Upper Torso injuries)

NUMBER OF SURVIVORS	WITHOUT DORSAL SPINE INJURY	WITH DORSAL SPINE INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	877	23 (2.3%)	1000
NOT USING BELTS	38	1 (2.6%)	39
TOTAL	915	24	1039

DIFFERENCE	+ .3%
CHI-SQUARE	0
P-VALUE	1.0

Test 12

Injuries of the Dorsal Spine With
Other Upper Torso Injuries

NUMBER OF SURVIVORS	WITHOUT DORSAL SPINE INJURY	WITH DORSAL SPINE INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	994	6 (.6%)	1000
NOT USING BELTS	38	1 (2.6%)	39
TOTAL	1032	7	1039

DIFFERENCE	+ 2.0%
CHI-SQUARE	.22
P-VALUE	.64

Test 13

Injuries of the Upper Torso Without
Dorsal Spine Injuries

NUMBER OF SURVIVORS	WITHOUT UPPER TORSO INJURY	WITH UPPER TORSO INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	829	171 (17.1%)	1000
NOT USING BELTS	35	4 (10.3%)	39
TOTAL	864	175	1039

DIFFERENCE	- 6.8%
CHI-SQUARE	.85
P-VALUE	.36

Test 14

Intra-Thoracic Injuries

NUMBER OF SURVIVORS	WITHOUT INTRA-THORACIC INJURY	WITH INTRA-THORACIC INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	978	22 (2.2%)	1000
NOT USING BELTS	39	0 (0%)	39
TOTAL	1011	22	1039

DIFFERENCE − 2.2%
CHI-SQUARE .12
P-VALUE .73

Test 15

Any Injury of the Neck (Cervical Spine Injuries Included)

NUMBER OF SURVIVORS	WITHOUT NECK INJURY	WITH NECK INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	940	60 (6.0%)	1000
NOT USING BELTS	36	3 (7.7%)	39
TOTAL	976	63	1039

DIFFERENCE + 1.7%
CHI-SQUARE .03
P-VALUE .86

Test 16

Injuries of the Neck Without Cervical Spine Injuries

NUMBER OF SURVIVORS	WITHOUT NECK INJURY	WITH NECK INJURY	TOTAL NUMBER OF SURVIVORS
USING BELT	964	36 (3.6%)	1000
NOT USING BELTS	37	2 (5.1%)	39
TOTAL	1001	38	1039

DIFFERENCE + 1.5%
CHI-SQUARE .004
P-VALUE > .92

Test 17

Any Spine Injury (Cervical, Dorsal or Lumbar)

NUMBER OF SURVIVORS	WITHOUT SPINE INJURY	WITH SPINE INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	840	160 (16.0%)	1000
NOT USING BELTS	35	4 (10.3%)	39
TOTAL	875	164	1039

DIFFERENCE — 5.7%
CHI-SQUARE .52
P-VALUE .47

Test 18

Dangerous-to-life Spine Injuries

NUMBER OF SURVIVORS	WITHOUT DANGEROUS SPINE INJURY	WITH DANGEROUS SPINE INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	900	100 (10.0%)	1000
NOT USING BELTS	37	2 (5.1%)	39
TOTAL	937	102	1039

DIFFERENCE — 4.9%
CHI-SQUARE .53
P-VALUE .47

Test 19

Any Injuries of the Lumbar Spine

NUMBER OF SURVIVORS	WITHOUT LUMBAR SPINE INJURY	WITH LUMBAR SPINE INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	884	116 (11.6%)	1000
NOT USING BELTS	37	2 (5.1%)	39
TOTAL	921	118	1039

DIFFERENCE — 6.5%
CHI-SQUARE .95
P-VALUE .33

Test 20

Any Injuries of the Dorsal Spine

NUMBER OF SURVIVORS	WITHOUT DORSAL SPINE INJURY	WITH DORSAL SPINE INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	971	29 (2.9%)	1000
NOT USING BELTS	37	2 (5.1%)	39
TOTAL	1008	31	1039

DIFFERENCE + 2.2%
CHI-SQUARE .085
P-VALUE .76

Test 21

Any Injuries of the Cervical Spine

NUMBER OF SURVIVORS	WITHOUT CERVICAL SPINE INJURY	WITH CERVICAL SPINE INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	976	24 (2.4%)	1000
NOT USING BELTS	38	1 (2.5%)	39
TOTAL	1014	25	1039

DIFFERENCE + .1%
CHI-SQUARE 0
P-VALUE 1.0

Test 22

Any Injury of the Head

NUMBER OF SURVIVORS	WITHOUT HEAD INJURY	WITH HEAD INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	618	382 (38.2%)	1000
NOT USING BELTS	6	33 (84.6%)	39
TOTAL	624	415	1039

DIFFERENCE + 46.4%
CHI-SQUARE 31.8
P-VALUE < .001

Test 23

Dangerous-To-Life Head Injuries

NUMBER OF SURVIVORS	WITHOUT DANGEROUS HEAD INJURY	WITH DANGEROUS HEAD INJURY	TOTAL NUMBER OF SURVIVORS
USING BELTS	847	153 (15.3%)	1000
NOT USING BELTS	23	16 (41.0%)	39
TOTAL	870	169	1039

DIFFERENCE	+ 25.7%
CHI-SQUARE	16.68
P-VALUE	$<$ .001

Test 24

Serious and Critical (Dangerous-To-Life) Injuries of the Head and Body

NUMBER OF SURVIVORS	WITHOUT SERIOUS OR CRITICAL HEAD AND BODY INJURIES	WITH SERIOUS OR CRITICAL HEAD AND BODY INJURIES	TOTAL NUMBER OF SURVIVORS
USING BELTS	715	285 (28.5%)	1000
NOT USING BELTS	18	21 (53.8%)	39
TOTAL	733	306	1039

DIFFERENCE	+ 25.3%
CHI-SQUARE	10.5
P-VALUE	$<$ .001

Tests 25 - 44
RELATIONSHIP BETWEEN THE OCCURRENCE OF INJURY AND FAILURE OF SAFETY BELT INSTALLATIONS

Test 25

Any Injury of the Lower Torso, Lumbar Spine Injuries Included

NUMBER OF SURVIVORS	WITHOUT LOWER TORSO INJURY	WITH LOWER TORSO INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	601	121 (16.8%)	722
WHOSE BELT INSTALLATION FAILED	118	103 (46.6%)	221
TOTAL	719	224	943

DIFFERENCE + 29.8%
CHI-SQUARE 81.45
P-VALUE < .001

Test 26

Injuries of the Lumbar Spine Only (no other Lower Torso Injuries)

NUMBER OF SURVIVORS	WITHOUT LUMBAR SPINE INJURY	WITH LUMBAR SPINE INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	704	18 (2.5%)	722
WHOSE BELT INSTALLATION FAILED	148	73 (33.0%)	221
TOTAL	852	91	943

DIFFERENCE + 30.5%
CHI-SQUARE 177.1
P-VALUE < .001

Test 27

Injuries of the Lumbar Spine With Other Lower Torso Injuries

NUMBER OF SURVIVORS	WITHOUT LUMBAR SPINE INJURY	WITH LUMBAR SPINE INJURY	TOTAL NUMBER SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	716	6 (.8%)	722
WHOSE BELT INSTALLATION FAILED	210	11 (4.9%)	221
TOTAL	926	17	943

DIFFERENCE + 4.1%
CHI-SQUARE 13.9
P-VALUE < .001

Test 28

Injuries of the Lower Torso Without Lumbar Spine Injuries

NUMBER OF SURVIVORS	WITHOUT LOWER TORSO INJURY	WITH LOWER TORSO INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	643	79 (10.9%)	722
WHOSE BELT INSTALLATION FAILED	184	37 (16.7%)	221
TOTAL	827	116	943

DIFFERENCE + 5.8%
CHI-SQUARE 4.8
P-VALUE .03

Test 29

Intra-Abdominal Injuries

NUMBER OF SURVIVORS	WITHOUT INTRA-ABDOMINAL INJURY	WITH INTRA-ABDOMINAL INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	707	15 (2.1%)	722
WHOSE BELT INSTALLATION FAILED	209	12 (5.4%)	221
TOTAL	916	27	943

DIFFERENCE + 3.3%
CHI-SQUARE 5.67
P-VALUE .02

Test 30

Any Injury of the Upper Torso, Dorsal Spine Injuries Included

NUMBER OF SURVIVORS	WITHOUT UPPER TORSO INJURY	WITH UPPER TORSO INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	694	128 (17.7%)	722
WHOSE BELT INSTALLATION FAILED	151	70 (31.7%)	221
TOTAL	745	198	943

DIFFERENCE + 14.4%
CHI-SQUARE 33.21
P-VALUE < .001

Test 31

Injuries of the Dorsal Spine Only
(no other Upper Torso Injuries)

NUMBER OF SURVIVORS	WITHOUT DORSAL SPINE INJURY	WITH DORSAL SPINE INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	707	15 (2.1%)	722
WHOSE BELT INSTALLATION FAILED	216	5 (2.3%)	221
TOTAL	923	20	943

DIFFERENCE + .2%
CHI-SQUARE 0
P-VALUE 1.0

Test 32

Injuries of the Dorsal Spine With
Other Upper Torso Injuries

NUMBER OF SURVIVORS	WITHOUT DORSAL SPINE INJURY	WITH DORSAL SPINE INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	717	5 (.7%)	722
WHOSE BELT INSTALLATION FAILED	221	0 (0%)	221
TOTAL	938	5	943

DIFFERENCE − .7%
CHI-SQUARE .45
P-VALUE .50

Test 33

Injuries of the Upper Torso Without
Dorsal Spine Injuries

NUMBER OF SURVIVORS	WITHOUT UPPER TORSO INJURY	WITH UPPER TORSO INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	614	108 (15.0%)	722
WHOSE BELT INSTALLATION FAILED	156	65 (29.4%)	221
TOTAL	770	173	943

DIFFERENCE + 14.4%
CHI-SQUARE 22.19
P-VALUE < .001

Test 34

Intra-Thoracic Injuries

NUMBER OF SURVIVORS	WITHOUT INTRA-THORACIC INJURY	WITH INTRA-THORACIC INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	712	10 (1.4%)	722
WHOSE BELT INSTALLATION FAILED	213	8 (3.6%)	221
TOTAL	925	18	943

DIFFERENCE + 2.2%
CHI-SQUARE 3.38
P-VALUE .06

Test 35

Any Injury of the Neck (Cervical Spine Injuries Included)

NUMBER OF SURVIVORS	WITHOUT NECK INJURY	WITH NECK INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	685	37 (5.1%)	722
WHOSE BELT INSTALLATION FAILED	203	18 (8.1%)	221
TOTAL	888	55	943

DIFFERENCE + 3.0%
CHI-SQUARE 2.25
P-VALUE .13

Test 36

Injuries of the Neck Without Cervical Spine Injuries

NUMBER OF SURVIVORS	WITHOUT NECK INJURY	WITH NECK INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	697	25 (3.5%)	722
WHOSE BELT INSTALLATION FAILED	211	10 (4.5%)	221
TOTAL	908	35	943

DIFFERENCE + 1.0%
CHI-SQUARE .28
P-VALUE .60

Test 37

Any Spine Injury (Cervical, Dorsal or Lumbar)

NUMBER OF SURVIVORS	WITHOUT SPINE INJURY	WITH SPINE INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	610	112 (15.5%)	722
WHOSE BELT INSTALLATION FAILED	188	33 (14.9%)	221
TOTAL	798	145	943

DIFFERENCE − .6%
CHI-SQUARE 0
P-VALUE 1.0

Test 38

Dangerous-To-Life Spine Injuries

NUMBER OF SURVIVORS	WITHOUT DANGEROUS SPINE INJURY	WITH DANGEROUS SPINE INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	651	71 (9.8%)	722
WHOSE BELT INSTALLATION FAILED	200	21 (9.5%)	221
TOTAL	851	92	943

DIFFERENCE − .3%
CHI-SQUARE .00006
P-VALUE > .92

Test 39

Any Injury of the Lumbar Spine

NUMBER OF SURVIVORS	WITHOUT LUMBAR SPINE INJURY	WITH LUMBAR SPINE INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	638	24 (3.3%)	722
WHOSE BELT INSTALLATION FAILED	137	84 (38.0%)	221
TOTAL	835	108	943

DIFFERENCE + 34.7%
CHI-SQUARE 153.5
P-VALUE < .001

Test 40

Any Injury of the Dorsal Spine

NUMBER OF SURVIVORS	WITHOUT DORSAL SPINE INJURY	WITH DORSAL SPINE INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	702	20 (2.8%)	722
WHOSE BELT INSTALLATION FAILED	216	5 (2.3%)	221
TOTAL	918	25	943

DIFFERENCE	- .5%
CHI-SQUARE	.028
P-VALUE	.86

Test 41

Any Injury of the Cervical Spine

NUMBER OF SURVIVORS	WITHOUT CERVICAL SPINE INJURY	WITH CERVICAL SPINE INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	710	12 (1.7%)	722
WHOSE BELT INSTALLATION FAILED	213	8 (3.6%)	221
TOTAL	923	20	943

DIFFERENCE	+ 1.9%
CHI-SQUARE	2.24
P-VALUE	.14

Test 42

Any Injury of the Head

NUMBER OF SURVIVORS	WITHOUT HEAD INJURY	WITH HEAD INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	170	552 (76.5%)	722
WHOSE BELT INSTALLATION FAILED	26	195 (88.2%)	221
TOTAL	196	747	943

DIFFERENCE	+ 11.7%
CHI-SQUARE	13.52
P-VALUE	$<$ .001

Test #3

Dangerous-To-Life Head Injuries

NUMBER OF SURVIVORS	WITHOUT DANGEROUS HEAD INJURY	WITH DANGEROUS HEAD INJURY	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	649	73 (10.1%)	722
WHOSE BELT INSTALLATION FAILED	156	65 (29.4%)	221
TOTAL	805	138	943

DIFFERENCE + 19.3%
CHI-SQUARE 48.98
P-VALUE < .001

Test #4

Serious and Critical (Dangerous-To-Life) Injuries of the Head and Body

NUMBER OF SURVIVORS	WITHOUT SERIOUS OR CRITICAL HEAD AND BODY INJURIES	WITH SERIOUS OR CRITICAL HEAD AND BODY INJURIES	TOTAL NUMBER OF SURVIVORS
WHOSE BELT INSTALLATION REMAINED INTACT	556	166 (23.0%)	722
WHOSE BELT INSTALLATION FAILED	133	88 (39.8%)	221
TOTAL	689	254	943

DIFFERENCE + 16.8%
CHI-SQUARE 23.41
P-VALUE < .001

Tests 45 - 64

RELATIONSHIP BETWEEN THE OCCURRENCE OF INJURY AND PRINCIPAL DIRECTION IN WHICH CRASH FORCE ACTS

Test 45

Any Type of Head Damage

NUMBER OF SURVIVORS	WITHOUT HEAD INJURY	WITH HEAD INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	95	485 (83.6%)	580
IN 'VERTICAL FORCE' CRASHES	30	86 (74.1%)	116
TOTAL	125	571	696

DIFFERENCE - 9.5%
CHI-SQUARE 5.37
P-VALUE .02

Test 46

Serious and Critical Head Injuries

NUMBER OF SURVIVORS	WITH NO DANGEROUS HEAD INJURY	WITH DANGEROUS HEAD INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	475	105 (18.1%)	580
IN 'VERTICAL FORCE' CRASHES	104	12 (10.3%)	116
TOTAL	579	117	696

DIFFERENCE - 7.8%
CHI-SQUARE 3.59
P-VALUE .06

Test 47

Serious and Critical (Dangerous-To-Life) Injuries of the Head and Body

NUMBER OF SURVIVORS	WITHOUT SERIOUS OR CRITICAL HEAD AND BODY INJURIES	WITH SERIOUS OR CRITICAL HEAD AND BODY INJURIES	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	430	150 (25.9%)	580
IN 'VERTICAL FORCE' CRASHES	57	59 (50.9%)	116
TOTAL	487	209	696

DIFFERENCE + 25.0%
CHI-SQUARE 27.67
P-VALUE < .001

Test 48

Any Injury of the Lower Torso, Lumbar Spine Injuries Included

NUMBER OF SURVIVORS	WITHOUT LOWER TORSO INJURY	WITH LOWER TORSO INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	495	85 (14.7%)	580
IN 'VERTICAL FORCE' CRASHES	52	64 (55.2%)	116
TOTAL	547	149	696

DIFFERENCE + 40.5%
CHI-SQUARE 92.16
P-VALUE < .001

Test 49

Injuries of the Lumbar Spine Only (no other Lower Torso Injuries)

NUMBER OF SURVIVORS	WITHOUT LUMBAR SPINE INJURY	WITH LUMBAR SPINE INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	567	13 (2.2%)	580
IN 'VERTICAL FORCE' CRASHES	76	40 (34.5%)	116
TOTAL	643	53	696

DIFFERENCE + 32.3%
CHI-SQUARE 138.9
P-VALUE < .001

Test 50

Injuries of the Lumbar Spine With Other Lower Torso Injuries

NUMBER OF SURVIVORS	WITHOUT LUMBAR SPINE INJURY	WITH LUMBAR SPINE INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	577	3 (.5%)	580
IN 'VERTICAL FORCE' CRASHES	106	10 (8.6%)	116
TOTAL	683	13	696

DIFFERENCE + 8.1%
CHI-SQUARE 31.37
P-VALUE < .001

Test 51

Injuries of the Lower Torso Without Lumbar Spine Injuries

NUMBER OF SURVIVORS	WITHOUT LUMBAR SPINE INJURY	WITH LUMBAR SPINE INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	511	69 (11.9%)	580
IN 'VERTICAL FORCE' CRASHES	102	14 (12.1%)	116
TOTAL	613	83	696

DIFFERENCE + .2%
CHI-SQUARE 0
P-VALUE 1.0

Test 52

Intra-Abdominal Injuries

NUMBER OF SURVIVORS	WITHOUT INTRA-ABDOMINAL INJURY	WITH INTRA-ABDOMINAL INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	564	16 (2.8%)	580
IN 'VERTICAL FORCE' CRASHES	107	9 (7.8%)	116
TOTAL	671	25	696

DIFFERENCE + 5.0%
CHI-SQUARE 5.77
P-VALUE .02

Test 53

Any Injury of the Upper Torso, Dorsal Spine Injuries Included

NUMBER OF SURVIVORS	WITHOUT UPPER TORSO INJURY	WITH UPPER TORSO INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	458	122 (21.0%)	580
IN 'VERTICAL FORCE' CRASHES	90	26 (22.4%)	116
TOTAL	548	148	696

DIFFERENCE + 1.4%
CHI-SQUARE .038
P-VALUE .84

Test 54

Injuries of the Dorsal Spine Only
(no other Upper Torso Injuries)

NUMBER OF SURVIVORS	WITHOUT DORSAL SPINE INJURY	WITH DORSAL SPINE INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	576	4 (.7%)	580
IN 'VERTICAL FORCE' CRASHES	107	9 (7.8%)	115
TOTAL	683	13	696

DIFFERENCE + 7.1%
CHI-SQUARE 23.2
P-VALUE < .001

Test 55

Injuries of the Dorsal Spine With Other Upper Torso Injuries

NUMBER OF SURVIVORS	WITHOUT DORSAL SPINE INJURY	WITH DORSAL SPINE INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	579	1 (.2%)	580
IN 'VERTICAL FORCE' CRASHES	114	2 (1.7%)	116
TOTAL	693	3	696

DIFFERENCE + 1.5%
CHI-SQUARE 3.15
P-VALUE .07

Test 56

Injuries of the Upper Torso Without Dorsal Spine Injuries

NUMBER OF SURVIVORS	WITHOUT UPPER TORSO INJURY	WITH UPPER TORSO INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	463	117 (20.2%)	580
IN 'VERTICAL FORCE' CRASHES	101	15 (12.9%)	116
TOTAL	564	132	696

DIFFERENCE - 7.3%
CHI-SQUARE 2.88
P-VALUE .09

Test 57

Intra-Thoracic Injuries

NUMBER OF SURVIVORS	WITHOUT INTRA-THORACIC INJURY	WITH INTRA-THORACIC INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	563	17 (2.9%)	580
IN 'VERTICAL FORCE' CRASHES	115	1 (.9%)	116
TOTAL	678	18	696

DIFFERENCE - 2.0%
CHI-SQUARE .93
P-VALUE .33

Test 58

Any Injury of the Neck (Cervical Spine Injuries Included

NUMBER OF SURVIVORS	WITHOUT NECK INJURY	WITH NECK INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	543	37 (6.4%)	580
IN 'VERTICAL FORCE' CRASHES	110	6 (5.2%)	116
TOTAL	653	43	696

DIFFERENCE - 1.2%
CHI-SQUARE .073
P-VALUE .79

Test 59

Injuries of the Neck Without Cervical Spine Injuries

NUMBER OF SURVIVORS	WITHOUT NECK INJURY	WITH NECK INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	558	22 (3.8%)	580
IN 'VERTICAL FORCE' CRASHES	113	3 (2.6%)	116
TOTAL	671	25	696

DIFFERENCE - 1.2%
CHI-SQUARE .12
P-VALUE .73

Test 60

Any Spine Injury (Cervical, Dorsal or Lumbar)

NUMBER OF SURVIVORS	WITHOUT SPINE INJURY	WITH SPINE INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	541	39 (6.7%)	580
IN 'VERTICAL FORCE' CRASHES	60	56 (48.3%)	116
TOTAL	601	95	696

DIFFERENCE + 41.6%
CHI-SQUARE 138.9
P-VALUE < .001

Test 61

Dangerous-To-Life Spine Injuries

NUMBER OF SURVIVORS	WITHOUT DANGEROUS SPINE INJURY	WITH DANGEROUS SPINE INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	561	19 (3.3%)	580
IN 'VERTICAL FORCE' CRASHES	74	42 (36.2%)	116
TOTAL	635	61	696

DIFFERENCE + 32.9%
CHI-SQUARE 128.2
P-VALUE < .001

Test 62

Any Injury of the Lumbar Spine

NUMBER OF SURVIVORS	WITHOUT LUMBAR SPINE INJURY	WITH LUMBAR SPINE INJURY	TOTAL NUMBER OF SURVIVORS
IN 'LONGITUDINAL FORCE' CRASHES	561	19 (3.3%)	580
IN 'VERTICAL FORCE' CRASHES	69	47 (40.5%)	116
TOTAL	630	66	696

DIFFERENCE + 37.2%
CHI-SQUARE 153.25
P-VALUE < .001

Test 63

Any Injury of the Dorsal Spine

Number of Survivors	Without Dorsal Spine Injury	With Dorsal Spine Injury	Total Number of Survivors
In 'Longitudinal Force' Crashes	575	5 (.9%)	580
In 'Vertical Force' Crashes	105	11 (9.5%)	116
Total	680	16	696

Difference + 8.6%
Chi-Square 28.47
P-Value < .001

Test 64

Any Injury of the Cervical Spine

Number of Survivors	Without Cervical Spine Injury	With Cervical Spine Injury	Total Number of Survivors
In 'Longitudinal Force' Crashes	565	15 (2.6%)	580
In 'Vertical Force' Crashes	114	2 (1.7%)	116
Total	679	17	696

Difference - .9%
Chi-Square .054
P-Value .82

APPENDIX 4

Scale* Used by Crash Injury Research in Classifying Degree of Body Injury

Statistical studies dealing with trauma usually are concerned with various aspects of injury problems, such as numbers and rates of "serious" and "fatal" injuries, the assessment of disability, loss of work-time, or some combination of these in terms of dollars and cents. The term "serious injury" has been commonly used as a catch-all "degree" for all degrees of injury from a broken nose to a depressed skull fracture with critical damage of the brain. Actually, there are many degrees of survivable injury, ranging from minor bruises and lacerations through painful and temporarily disabling fractures, up to truly "serious" injuries which threaten life. Further, "fatal injury" as a descriptive class is not meaningful for conveying the extent of overall bodily damage. "Fatality" is in fact a state of non-being. It does not distinguish, for example, between fatality consisting of one mortal lesion and fatality consisting of multiple injuries with complete crushing or disintegration of the body.

Since Crash Injury Research seeks data on causes of needless and excessive bodily injury, it has been found desirable to develop an injury scale by which various degrees of overall bodily damage can be more easily defined. The injury-scale shown below has been developed over the past decade with the assistance of specialists and members of the staff of the New York Hospital - Cornell University Medical College. This scale is still under development and cannot be considered a measuring device for seriousness of injury; it is rather, a *guide* to enable accident-injury analysts to assess the overall severity of gross bodily damage. Ten progressive degrees of injury are outlined in terms of simple key words and phrases. Some examples of typical injuries are provided to serve as guides to the ten degrees of injury. It will be noted that many types of injuries are not included as examples; these injuries have not occurred with sufficient frequency to require specific listing. When exceptional types of injury occur, medical consultants have had no difficulty in assigning them to one of the ten degrees of injury-seriousness connoted by the key phrases. Quite obviously, skull fracture, with or without concussion, occurs with great frequency and in many gradations of "seriousness"; for this reason, injuries of this type have been listed for purposes of example and guidance.

A. "Non-Dangerous" Degrees of Injury
(Degrees 1 - 4)

1. *Trivial* or *None*

2. *Minor*

   "Minor" contusions, lacerations, abrasions in any area(s) of the body. Sprains, fractures, dislocations of fingers, toes, or nose. Dazed or

* BASED ON OBSERVATIONS DURING FIRST 48 HOURS AFTER INJURY AND PREVIOUSLY NORMAL LIFE EXPECTANCY.

slightly stunned. Mild concussion evidenced by mild headache, with no loss of consciousness

3. *Moderate*

"Moderate" contusions, lacerations, abrasions in any area(s) of the body. Sprains of the shoulders or principal articulations of the extremities. Uncomplicated, simple or green-stick fractures of extremities, jaw or malar structures. Concussion as evidenced by loss of consciousness not exceeding 5 minutes, without evidence of other intra- cranial injury.

4. *Severe - but not dangerous. Survival normally assured.*

Extensive lacerations without dangerous hemorrhage. Compound or comminuted fractures, or simple fractures with displacement. Dislocations of the arms, legs, shoulders or pelvisacral processes. Fracture of transverse and/or spinous processes of the spine, without evidence of spinal cord damage. Simple fractures of vertebral bodies of the dorsal and/or lumbar spines, without evidence of spinal cord damage. Compression fractures of L-3-4-5. Skull fracture without evidence of concussion or other intra-cranial injury. Concussion as evidenced by loss of consciousness from 5 to 30 minutes, without evidence of other intracranial injury.

B. "Dangerous-to-life" Degrees of Injury
(Degrees 5-6)

5. *Serious - dangerous, but survival probable.*

Lacerations with dangerous hemorrhage. Simple fractures of vertebral bodies of the cervical spine, without evidence of spinal cord damage. Compression fractures of vertebral bodies of dorsal spine and/or of L-1 and L-2, without evidence of spinal cord damage. Crushing of extremities, or multiple fractures. Indication of moderate intra-thoracic or intra-abdominal injury. Skull fracture with concussion as evidenced by loss of consciousness from 5 to 30 minutes. Concussion as evidenced by loss of consciousness from 30 minutes to 2 hours, without evidence of other intra-cranial injury.

6. *Critical - survival uncertain or doubtful.*

(Includes fatal terminations beyond 24 hours.) Evidence of dangerous intra-thoracic or intra-abdominal injury. Fractures or dislocations of vertebral bodies of cervical spine with evidence of cord damage. Compression fractures of vertebral bodies of dorsal spine and/or L-1, L-2, with evidence of spinal cord damage. Skull fracture, with concussion as evidenced by loss of consciousness from 30 minutes to 2 hours. Concussion as evidenced by loss of consciousness beyond 2 hours. Evidence of critical intra-cranial injury.

C. *"Fatal" Degrees of Injury*
(Degrees 7 - 10)

7. *Fatal - within 24 hours of accident.*

Fatal lesions in single region of the body, with or without other injuries to the 4th degree.

8. *Fatal - within 24 hours of accident.*

Fatal lesions in single region of the body, with other injuries to 5th or 6th degree.

9. *Fatal*

Two fatal lesions in two regions of the body, with or without other injuries elsewhere.

10. *Fatal*

Three or more fatal injuries - up to demolition of body.